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Neuropsychological Outcome In Relation To Duration Of Early Orphanage Experience

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NEUROPSYCHOLOGICAL OUTCOME IN RELATION TO DURATION OF EARLY ORPHANAGE EXPERIENCE

by

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DISSERTATION

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DEDICATION

This dissertation is dedicated to my family, particularly my husband, who has been an endless source of support and encouragement; and my parents, who instilled in me a love of learning and scientific inquiry.

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BACKGROUND

Institutionalization and global cognitive functioning

Children raised in orphanages have sparked the interest of researchers for decades as they provide an unfortunate natural experiment on the effects of severe environmental deprivation on young children. While the quality of international orphanages varies, numerous reports outline the deplorable conditions that many institutionalized children encounter. Reporting on the state of Romanian orphanages in the 1990s, Johnson et al. (1992) write that "most orphanages provided only subsistent levels of food, clothing, and shelter. The ratio of children to caregivers – often 60 to one – precluded personal contact. Infants were relegated to cribs, with little or no chance to interact with their peers. Toilet training and meal times were severely regimented" (p. 3446). The deleterious effects of orphanage experience on physical health are well documented and affect children around the world, including in Guatemala (L. Miller, 2005); China (L. C. Miller & Hendrie, 2000); Russia (Albers, Johnson, Hostetter, Iverson, & Miller, 1997); and Romania (Ames, 1997; Rutter & English and Romanian Adoptees (ERA) study team, 1998). Not surprisingly, early rearing in such a minimally stimulating environment is also related to lower cognitive functioning. In an early cross-sectional study evaluating a particular unnamed institution, Spitz (1945) reports that the average developmental quotient (DQ) of children aged nine to twelve months is measured at 72. Kaler and Freeman (1994) evaluate the developmental quotients of 25 children aged two to four years residing in a Romanian orphanage and find that none of the children were functioning at age level, and 20 were functioning at levels less than half of their chronological age. Sloutsky (1997b) evaluates the intellectual functioning (IQ) of 52 children aged five to seven years living in an orphanage in

Russia and reports the average IQ to be twenty points lower (M = 86) than a comparison group of family-reared children, with children who had been in the institution the longest having the lowest scores.

Much of the current research on children with early institutional experience examines the functioning of previously institutionalized children once they have been adopted. After placement in a family home, previously institutionalized children's environment is immediately and dramatically changed. Two longitudinal studies, one investigating children adopted into Canada (Ames, 1997) and the other investigating children adopted in the U.K. (Rutter & English and Romanian Adoptees (ERA) study team, 1998) provide the most information about the catch-up in cognitive functioning that occurs after adoption in previously institutionalized children. In the U.K. sample, they find that the majority of the catch-up occurs by the four-year-old assessment; individual scores remain largely consistent when the children are reassessed at both six and eleven years (Beckett et al., 2006; O'Connor et al., 2000). In a minor exception to the finding of stability of scores, Beckett et al. (2006), at the eleven year assessment, report that there is a limited amount of catch-up for the most impaired children (those who remained in the institution the longest). Despite this selective catch-up, many of these impaired children remain in the most impaired group. The Canadian sample also provides evidence for both catch-up and stability of scores. When children in the Canadian sample were assessed at 11 months post-adoption, the children were progressing at more than one month developmentally for each chronological month in their adoptive home (Morison, Ames, & Chisholm, 1995). Although individual rates of change were not evaluated in the Canadian sample, the ranking of average IQ scores across groups remains consistent when assessed at three years and then again when the children were at least nine-and-a-half- years-old. Taken together, these results suggest that the majority of catch-up occurs shortly after adoption, although the most impaired children may be more likely to show only limited improvements over time.

Despite any catch-up or recovery that may occur after placement in an adoptive or foster-care home, however, many previously institutionalized children continue to perform significantly less well than their never-institutionalized peers. Nelson et al. (2007) report that the average IQ of 59 54-month-old children remains 28 points lower than a never institutionalized comparison group (mean value 81 versus 109, respectively), even after being in a foster care home for an average of 33 months. In a longitudinal study of children adopted into the U.K. from Romanian institutions, the average global cognitive scores of adoptees remains below their never-institutionalized peers when they are assessed at four, six, eleven, and fifteen years of age (Beckett, Castle, Rutter, & Sonuga-Barke, 2010; Beckett, et al., 2006; O'Connor, et al., 2000; Rutter & English and Romanian Adoptees (ERA) study team, 1998).

One of the most consistently observed moderators of intellectual outcome for children with early orphanage experience who are later adopted or placed in foster care is duration of time children are institutionalized: longer stays in an institution are related to lower IQ, a finding that appears to hold true for orphanages globally (Loman, Wiik, Frenn, Pollak, & Gunnar, 2009). The effect of duration of institutionalization on IQ has been demonstrated both with continuous measures of duration and through group differences; and the relationship remains significant across time in longitudinal studies. The U.K. longitudinal study of Romanian adoptees (Rutter & English and Romanian Adoptees (ERA) study team, 1998) reports that the correlation between IQ score and age when children are placed in their adoptive home is -0.75 at age four years and -0.48 at age six years (Rutter, O'Connor, Beckett, & et al., 2000). Surprisingly, they fail to find a significant relationship at age eleven (Beckett, et al., 2006). It is argued by Maclean (2003), however, that participants in this sample who are adopted at later ages may have artificially elevated IQ scores, as children with little or no orphanage experience are included (close to 15% of the U.K. sample did not experience an institutional upbringing: some had been reared in a family setting and others had been institutionalized for as little as two weeks).

One longitudinal study of children adopted to Canada (Ames, 1997) reports correlations between IQ and age at adoption of r=-0.75 three years after adoption (Morison & Ellwood, 2000) and r=-0.44 nine years or more after adoption (Le Mare, Vaughan, Warford, & Fernyhough, 2001). Early-adopted children score the highest (M = 108), children adopted between 8 and 24 months score lower (M=89), and children who had been adopted after age two score the lowest of all (M=71). O'Connor et al. (2000) report that the time spent in an institution is a stronger predictor of intellectual functioning at both ages four and six than are either birth weight or developmental status at adoption. Morison (2000) reports that the length of stay in the institution is the only variable related to intelligence, even when considering the child's health, birth weight, quality of the institution, the availability of toys, the child's weight at adoption, and whether the child was a favorite of a caregiver in the institution. Clearly, the length of the child's stay in the orphanage is a critical factor to evaluate when considering child intellectual outcome.

Sensitive Periods in Development: Theoretical Overview

The dramatic contrast in experience between institutional and family life, and the finding that the duration of time a child experiences institutionalization is a strong predictor of outcome, poses the question of whether there is a sensitive period, or a window of opportunity, when a child's development is most affected by the severe deprivation of institutionalization. A sensitive period refers to "the idea that having a certain kind of experience at one point in development has a profoundly different impact on future behavior than having that same experience at any other point in development" (Bruer, 2001, p. 4). Sensitive periods were first observed in embryology in the 1920s when Charles Stockard demonstrated that specific and discrete birth defects occur following toxic exposure during select times in embryonic development (Stockard, 1921). Evidence of sensitive periods in *brain* development has most popularly been demonstrated via the study of binocular development in cats by Hubel and Wiesel (1962). Hubel and Wiesel demonstrate that synaptic wiring in the brain is not genetically determined but is shaped by environmental experience during specific periods in postnatal development.

Two distinct types of environmental stimulation are suggested by Greenough, Black and Wallace (1987) as potentially representing different models of neural plasticity, and thus may demonstrate differing relations with regard to sensitive periods. These include "experience-expectant" stimulation, and "experience dependent" stimulation. Research demonstrates that a child's brain development is supported by receiving everyday kinds of stimulation that are expected and naturally occurring (experience-expectant). Greenough, Black and Wallace (1987, p. 540) argue that "an important component of the neural processes underlying experience-expectant information storage appears to be the intrinsically governed generation of an excess of synaptic connections among neurons, with experiential input subsequently determining which of them survive." In contrast, experience-dependent stimulation refers to the unique kinds of experience that individuals may receive that can vary from individual to individual such as learning a specific language, learning culturally-specific ways of expressing emotion, or learning to play the violin. Greenough, Black and White (1987) state that "an important aspect of the mechanism underlying experience-dependent information storage appears to be the generation of new synaptic connections in response to the occurrence of a to-be-remembered event."

In evaluating sensitive periods and neural plasticity among children raised in orphanages, much of the observation is typically placed on experience-expectant stimulation and the related theories of neural plasticity. However, it is important to remember that children raised in institutions often lack both experience-expectant and experience-dependent types of stimulation, to a large extent. And, importantly, as Fox, Levitt and Nelson (2010, p. 28) point out, "it is made clear that later experience also plays an important role in maintaining and elaborating this early wiring diagram [created by experience-expectant stimulation], which is critical to establishing a solid footing for development beyond the early years."

Possible neurological mechanisms to explain observed sensitive periods include the outgrowth of dendrites and the creation of new synapses; and increased neuronal efficiency through myelination, apoptosis, and pruning of existing synapses. Genesis of human cortical neurons and neocortical migration are both largely complete by approximately the second trimester of pregnancy (a minor exception is evidence of limited cortical generation in the dentate gyrus and olfactory bulb throughout the lifespan). The fastest cortex expansion and, relatedly, the fastest dendritic outgrowth, lasts until about four years of age. In humans, after 5 years of age, a large inter-individual variation in dendritic tree size becomes apparent. Certain human cortical areas, such as the frontal and parietal cortices, keep increasing in growth until the age of about 12-13 years (for a review of human cortical development see Uylings, 2006). The brain is not thought to be fully mature until 15-20 years of age when considering the size and density of neurons, the extent of dendritic branching, the number and density of synapses, the pharmacological composition of the brain, and the electrophysiological response of the brain (Lichtman, 2001). Thus, during this 15-20 year period, the brain has the potential to be continually shaped by environmental input.

A longitudinal MRI study (Giedd et al., 1999) finds a continuous increase in the brain's overall white matter volume between 4-21 years. Several examples of unique timing and duration for individual cortical areas show that this myelination process is non-uniform. For example, during Giedd et al.'s study period of 4-21 years the posterior part of the corpus callosum changes continuously but not the anterior part. Separate postmortem studies (e.g. Brody, Kinney, Kloman, & Gilles, 1987) show that the myelin development below and in the primary motor and sensory areas are ahead of those of the associational frontal, parietal and temporal areas. Counting the number of synapses in different brain areas taken from individuals of varying ages post-mortem, Huttenlocher & Dabholkar (1997) illustrate that synaptic densities in the human brain change over the life span. In every area, Huttenlocher & Dabholkar find a period of rapid density increase followed by a period of decrease. This paradoxical decrease with increased development is thought to be due to selective pruning of synapses in order to create greater overall neural efficiency. Huttenlocher & Dabholkar report that the decrease in synaptic density is not observed to plateau until adolescence. Collectively, these studies indicate that different brain regions mature at different periods in development and suggest the potential for separate brain regions, and their associated cognitive processes, to demonstrate unique periods when they are most sensitive to environmental input.

Sensitive Periods for Language and Other Cognitive Processes

Sensitive periods for language processes are suggested by studies to evaluate the development of a number of special populations, including individuals with hearing impairment, individuals with focal brain injury, and cross-cultural studies of first and second language acquisition. Phonology, semantic processing, and grammatical processing are all discussed separately as research exists to suggest that each of these present a unique picture.

In evaluating phonology, Werker et al. (1981) demonstrate that English-exposed 7-month olds are able to distinguish between two uniquely Hindi phonemes, while English speaking adults are not. Subsequent studies suggest that sensitivity for discrimination of novel phonemes declines between the first 6-12 months of an infant's life (J. Werker & Lalonde, 1988). However, contrary to popular knowledge, the ability to discriminate phonemes may never disappear altogether as an adult who has never been exposed to foreign phonemes may be able to distinguish among them with proper training (Flege, Naoyuki, & Mann, 1995). Note that the acquisition of this discrimination ability is more effortful at later ages.

Evidence supports that among typically developing individuals, semantic processing (or the ability to attribute meaning to words) involves the posterior areas of both hemispheres; while, processing grammatical information primarily activates anterior regions of the left hemisphere (Neville, Nicol, Barss, Forster, & Garrett, 1991). This typical pattern of neural specialization is found to differ among special populations who are not exposed to language at critical periods in early development, potentially suggesting that environmental input during early sensitive periods is required for typical neural organization. For example, Neville, Mills & Lawson (1992) demonstrate differing brain activation between deaf and hearing children when processing written English words. They find that between deaf and hearing groups the evoked response potential indices of semantic processing are virtually identical, while those linked to grammatical processes are markedly different. Neville et. al. note that many deaf children never fully master English grammar and theorize that these observed differences between deaf and hearing children may be due to the fact that many deaf children learn English at a later time period than hearing children.

Weber-Fox and Neville (1996) evaluate early and late second language learners to determine whether there is a difference in brain activation in response to semantic and grammatical processing of a novel language, when compared to native speaking bilinguals. Weber-Fox and Neville find that the brain systems that mediate semantic processing do not demonstrate significant differences in early or late language learners and conclude that “unusual early language experience does not have large effects on how semantic processing is organized in the brain”. In contrast to semantic processing, children who learned a second language between ages one and three develop a similar left-hemisphere activation for grammatical processing as native speakers, but second language learners who begin to learn the language later in childhood (between the ages of 4-6 years) demonstrate a pattern of activation that is more bilateral than native speakers. Thus, the authors conclude that “the grammatical subsystem is more sensitive to early experience than the semantic system”.

Deaf children’s attainment of sign language also provides more insight into sensitive periods in the development of language. A strong predictor of a deaf child’s eventual grammatical fluency is the age at which they are first exposed to sign language(Newport, 1990). Newport compares the expressive and receptive language (using ASL) of three groups of people who were deaf from birth. All participants had been using ASL as their primary means of communication for at least 30 years. The first group learned ASL from birth, the second group learned ASL between the ages of 4 and 6, and the third group learned ASL after age 12. Newport finds that only the ASL speakers in the first two groups speak ASL with a native-fluency. The second group demonstrates some nonnative characteristics in their speech. Those in the latest-learning group demonstrate significant language deficits. Many of the problems in this later group have to do with complex syntactic structures within sentences. Taken together, these studies suggest a sensitive period for grammatical processing that is not observed for semantic processing.

These studies of language functioning among special populations demonstrate the presence of unique sensitive periods for development of different linguistic cognitive processes (including grammar, semantics, and phonology). There are also studies to suggest sensitive periods for the potential to protect linguistic functions after brain injury. In adults the left hemisphere is typically devoted to language functions. After focal injury to the left hemisphere regions that are responsible for language functioning, adults commonly develop acquired aphasia (Goodglass, 1993). These same functional language impairments are rarely observed in children with focal brain injury, however, reflecting the brain's capacity to reorganize these same functions to different areas of the brain (also known as neuroplasticity). Because the outcomes of children with lesions are much better than the outcomes for adults with lesions, neuroplasticity for language must decrease markedly at some point between birth and adulthood. Several studies to evaluate global IQ after an early left hemisphere focal lesion find that children with lesion onset between one and five years of age score worse than children with either a congenital lesion or a lesion acquired between the ages of five and twelve (Goodman & Yude, 1996; Vargha-Khadem, Isaacs, & muter, 1994). These results indicate that there is not a simple linear drop in plasticity observed during childhood, and exemplify the complexity of the study of sensitive periods.

Unfortunately, much less is known about sensitive periods for other cognitive processes. There is some research indicating different developmental trajectories for spatial reasoning, language, and executive functioning, however, which suggests the potential for unique periods when these processes are most sensitive to environmental input. Research of children with early focal brain injury suggests that early left-localized lesion does not result in worse performance on language measures after middle childhood (see E. Bates, Vicari, & Trauner, 1999, for a review) but, in contrast, children with early right-localized lesion *do* demonstrate persisting specific deficits in spatial cognition (Stiles, Bates, Thal, Trauner, & Reilly, 2002). Synthesizing these observations, Stiles et. Al. (2002) conclude that language is more plastic than spatial cognition, perhaps because “language is dependent on a wide array of interlocking neural systems”. The development of executive functioning processes also provides a contrast to either language or spatial cognition. In comparison with the functional sequelae of early left hemisphere lesion (which demonstrate an attenuating impairment profile with increasing age), early focal lesion to the frontal poles demonstrates increasing deficit with increasing age possibly because demands for behaviors mediated by the frontal lobes may become more pronounced as children reach adolescence (Eslinger & Grattan, 1991). Additionally, Huttenlocher & Dabholkar’s (1997) work with synaptic densities indicates that the frontal regions are the last to mature. Thus, it is likely that the cognitive processes mediated by these anterior regions are moderated by environmental influences at a later time, or for a longer duration of time, than other neural regions.

Previously Institutionalized Children as an Unfortunate Natural Experiment in Sensitive Periods

Several prior researchers have specifically searched for the presence of a sensitive period for cognitive outcome among institutionalized children. An early cross-sectional study (Dennis, 1973) emphasizes two-years of age as a turning point for the global IQ of children in institutions. After describing the conditions of a particular orphanage in Lebanon, including the impaired cognitive scores of its inhabitants (mean DQ of 50 at one year of age and a mean IQ of 62 in adolescence), Dennis notes that, when assessed at various ages after adoption, the mean IQ of children adopted before age two is in the average range (94 for children adopted prior to one year and 96 for children adopted between one and two years of age). In contrast, children adopted after two years of age score an average of twenty points lower (81 for children adopted between two and four years of age, and 79 for children adopted after age 4).

Interestingly, at the time of assessment, the later-adopted children had been in their adoptive homes for longer than the earlier-adopted children. This cross-sectional snapshot suggests a nonlinear drop-off in scores after two-years of institutional experience that is not completely remediated by adoption.

The English and Romanian Adoptees (ERA) study team (Rutter & English and Romanian Adoptees (ERA) study team, 1998) also evaluates their data for the presence of a threshold. They note that a scatter plot portraying the relationship between the duration of time the child remains in the institution and his/her DQ at 4 years indicates little age effect within the first 6 months, but an apparently linear effect thereafter, with longer duration associated with lower cognitive scores (average DQ for children adopted between 0-6 months is 105.9±17.9 as compared with 91.7±18.0 for children adopted between 6 and 24 months). This pattern suggests an adoption age of 6-months as a potential threshold for child outcome. When these children are reassessed at 6-years, however, there is no statistical evidence for a nonlinear relationship after accounting for the presence of a linear relationship, as may be observed if there were a threshold effect (O'Connor, et al., 2000).

Nelson, et al. (2007) report evidence of two-years-of age as a potentially critical time for removing children from orphanages in order to realize the greatest benefit of foster care. Evaluating a sample of 59 children who were placed into foster care after experiencing institutional rearing in Romania, Nelson et al. conduct five simultaneous t-tests to compare the effects of duration of institutionalization on IQ assessed at age 4.5 years (the sample was broken down to compare children adopted before and after ages 20, 22, 24, 26, and 28 months). Nelson et al. state that the greatest effect sizes are found for the 24 and 26 month analyses, suggesting that children placed before 2 years benefit the most from placement in foster care. Interestingly, although the data show the anticipated ordering of means with longer durations showing declining IQ scores at the 4.5 year assessment, Nelson et. al. fail to find significant differences in IQ by age at placement (broken down as 0-18, 18-24, 24-30, and 30-35 months). Considering the differing results indicated in these two analytic approaches, Nelson, et al. write that “at first glance our findings suggest that there may be a sensitive period spanning the first two years of life within which the onset of foster care exerts a maximal effect on cognitive development. However, a closer reading of our analyses suggests a more parsimonious conclusion: that the younger a child is when placed in foster care, the better the outcome” (p. 1940). It is suggested that “discovering whether such a [sensitive period in development] truly exists, or determining the borders that delineate it, would likely require a larger sample size with a broader age range at [foster placement]” (p. 1940).

Among our own sample, we have observe some suggestion of a critical period for impairment classification occurring around age two (Behen, Helder, Rothermel, Solomon, & Chugani, 2008). Looking at a composite score of the number of participants with at least one cognitive domain in the impaired range (as defined by an obtained score of two standard deviations below the normative mean score), a non-linear increase in the percentage of participants with impairment is observed for children who had remained in the institution for more than two years. Specifically, among children who have been in the orphanage for 6-12 months and then 13-20 months, 40 and 53%, respectively, demonstrate impairment in at least one cognitive domain. In contrast, among children who had been in the orphanage for 21-36 and >36 months, 75% and 88% demonstrate impairment. This analytic approach, however, is not specifically tailored to evaluate critical periods. This finding of a nonlinear increase in impairment classification could be explained, for example, by a linear relationship between duration and outcome with the average child's cognitive score reaching an impaired value after approximately two years of institutionalization experience.

Thus, in regards to global cognitive functioning, some studies suggest the possibility of a sensitive period where remaining in an orphanage past a certain threshold results in increasingly greater, nonlinear, impairment. These findings co-exist with the literature demonstrating a linear, or dose-response relationship of duration with intellectual outcome (Van Ijzendoorn, Luijk, & Juffer, 2008). More research is warranted to further explore the relationship of duration with outcome. Maclean (2003) notes that the great majority of children adopted since 1990 have been adopted before the age of 2, making it difficult to study children with longer-duration of orphanage experience. The sample that is employed in this study is uniquely situated to explore questions about duration, as a significant number of our participants had institutional experience lasting past two years of age (72 children in the current study's sample were adopted after age 20 months).

Comprehensive Neuropsychological Functioning of Previously Institutionalized Children

In addition to *global* cognitive functioning, researchers are now beginning to evaluate the relationship of institutionalization, per se, with *specific* cognitive domains such as academic achievement, language, executive functioning and memory. The existent literature on the comprehensive, neuropsychological functioning in previously institutionalized children is summarized below. Despite these limited studies, much less is known about the role that *duration* of orphanage experience has on these specific neuropsychological outcomes. Additionally, there have been no reported studies to examine whether a sensitive period, or threshold, is observed for these individual cognitive domains among children with a history of institutionalization.

Several researchers focus on the academic achievement of children with early orphanage experience. Le Mare et al. (2001) report a dose-response relationship with duration of orphanage experience and performance on a standardized achievement test at ages nine and above; children adopted before two years perform better than children adopted after age two. Beckett et al. (2007)'s evaluation of the academic achievement of eleven-year-old children demonstrates that a continuous measure of duration of institutional experience is only modestly correlated with basic reading and mathematical reasoning (r=-0.26 and r=-0.23, respectively) while the relation with reading comprehension (r=-0.10) is non-significant.

When evaluating the language of previously institutionalized children, Croft et al. (2007), evaluating the longitudinal sample of children adopted to the U.K., demonstrate that, at age 11, children with early orphanage experience lasting six months or longer perform worse on language measures than a never institutionalized control group. In this sample, they fail to find significant associations between duration of orphanage experience and language outcome in the six to twenty-four month range, similar to the findings for IQ in this sample (Beckett, et al., 2006)—i.e. duration, past six months, was not significant in their findings. As noted in the above discussion of IQ, however, these null results may be a function of the limited orphanage experience in the later adopted children. Most notably for this sample, Loman, Wiik, Frenn, Pollak & Gunnar (2009) report a significant correlation of duration of institutionalization when previously institutionalized children are assessed at eight to eleven years of age on two measures of receptive language (CELF Concepts and Following Directions r = -0.35 and CASL Paragraph Comprehension r = -0.36).

Finally, several published studies evaluate the areas of executive functioning and memory in previously institutionalized children. Among a sample of 93 eight-year-old children, Bos et al. (2009) fail to find differences among a previously institutionalized group and a never institutionalized group on a measure of problem solving and planning (the CANTAB Stockings of Cambridge), but they *do* find that previously institutionalized children score lower on a spatial working memory task (CANTAB), on a visual learning task (CANTAB paired associates learning), and on a visual memory task (CANTAB Delayed matching to sample). Despite these group differences, they do not find, however, a significant correlation between these outcome variables and a continuous measure of duration. In a separate study, Pollak et al. (2010) evaluate four broad cognitive domains including memory, attention, executive control, and learning. Participants in this study include 48 children who spent at least 75% of their lives prior to adoption in an institution. Pollak et.al. find measures of verbally-mediated memory, spatial learning, inhibition, and visual scanning relate to the duration of institutionalization while they failed to find a significant relation to measures of spatial working memory, visual memory, set-shifting, planning, and sustained attention. Participants in this sample had been institutionalized for a relatively wide-range of one to six years; however, participants were excluded if their global IQ was less than 78 which may have significantly attenuated the variance in this sample. Pollak et.al. fail to report whether participants who were excluded due to IQ had experienced the longest duration of institutionalization.

In summary, these researchers find that children with early orphanage experience demonstrate impairment, relative to never-institutionalized comparison groups, on select cognitive domains as well as one the more often studied global measures. To date, there has only been one published report of the comprehensive neuropsychological profile of children with early orphanage experience (Behen, et al., 2008). Behen reports that even in the absence of impairments in IQ, a substantial number of previously institutionalized children (46%) still demonstrate impairment on select cognitive domains, as defined by the test's normative sample. The most common areas of impairment include executive function (24%), language (18%), memory (17%), manual dexterity (11%), and academic achievement (5%). Interestingly, the length of time in the orphanage is the *only* significant predictor of the number of areas of impairment, even when considering the child's age at testing, the duration of time in an adoptive home, or the adoptive parent's education level, gender, head circumference, handedness, region of adoption, and behavioral functioning. This proposed project seeks to expand upon these findings with Behen's sample and evaluate the relationship of individual cognitive domains with *duration* of orphanage experience. Two primary study aims include evaluating 1) whether different cognitive domains demonstrate unique relations with duration of institutionalization and 2) which cognitive domains demonstrate the strongest relationship with duration of institutionalization.

METHODS

Participants

Participants were recruited as part of a larger study on the neurocognitive effects of early deprivation and the recruitment of participants and study procedures have been reported elsewhere (Behen, et al., 2008). One hundred forty five children aged 6-18 with early orphanage experience (61 males and 84 females) were recruited by support groups and from newsletters for parents who adopted a child internationally. In order to be eligible to participate, children must have been separated from their biological mother at birth and placed into an orphanage immediately after release from a hospital, the child must speak English, and he/she must attend school regularly (per parent report). Exclusion criteria include adoptive parent's knowledge of child's prematurity, pre- or peri-natal difficulties (including low birth weight), current or past major medical problems, epilepsy, evidence of focal neurological impairment on neurological examination, and/or evidence of fetal alcohol exposure, as assessed by a neurologist using the criteria outlined by Miller, et al. (2006).

Participants were adopted from orphanages around the planet. Regions of adoption include South/East Asia (N = 45; including China [n = 44] and Vietnam [n = 1]), Eastern Europe (N = 45; including Ukraine [n = 4], Romania [n = 25], Poland [n = 7], Kazakhstan [n = 2], Armenia [n = 2], Bulgaria [n = 1], and Slovakia [n = 1]), Northern Asia (N = 51; including Russia [n = 50] and Georgia [n = 1]), and Central or South America (N = 3; including Guatemala [n = 2] and Mexico [n = 1]). Participants spent an average of 25.9 months in an orphanage prior to adoption (range 3 months to 90 months). Mean age at testing was 9.4 years (*SD* 2.2).

At testing, participants had spent an average of 7.1 years (*SD* 2.7) in their adoptive home. Parental education status is available for 70% of the participants. All parents for whom education is known hold at least a high school education. The mean maternal education was 16.7 years (*SD* 2.1) and the mean paternal education was 16.7 years (*SD* 2.6). In fact, the parents of this sample are particularly well-educated. Of the parental education data that was obtained, 78% (*n* = 80) of the mothers are college graduates, and 38% (*n* = 39) hold a graduate degree. Similarly, 82% (*n* = 72) of the fathers are college graduates, and 36% (*n* = 32) hold a graduate degree.

Procedure

Participants were initially screened by telephone for inclusion/exclusion criteria and then scheduled for a 4-6 hour visit consisting of parental interview, and child neuropsychological and neurological examinations. The test battery included a comprehensive neuropsychological assessment. Intellectual functioning (IQ) was assessed by the Wechsler Intelligence Scales for Children – Third Edition (WISC-III; Wechsler, 1991; *n* = 107) or Fourth Edition (WISC-IV; Wechsler, 2003; *n* = 38), depending on the date that the child was assessed.

Expressive language was assessed by the Producing Word Associations subtest of the Clinical Evaluation of Language Fundamentals – Fourth Edition (CELF-IV; Semel, Wiig, & Secord, 2003). Receptive language was assessed by either the Concepts and Directions subtest of the CELF-IV, or by the total score of the Token Test for Children (Token Test; McGhee, Ehrler, & DiSimoni, 2007), depending on the date that the child was assessed. The Token Test and the

Concepts and Directions subtests require similar task demands, in that the child is asked to attend to and carry-out increasingly complex verbal commands.

Manipulative dexterity was assessed with the Grooved Pegboard Test (Grooved Pegs; Trites, 1989). Performance for both dominant and nondominant hands will be evaluated in analyses.

Two aspects of executive functioning were assessed with the Gordon Diagnostic System (GDS; Gordon, 1996). Impulse control was assessed by the GDS Vigilance Commissions (False Alarms), and sustained attention was assessed by the GDS Vigilance Omissions (Hits).

Memory was assessed with the Wide Range Assessment of Memory and Learning, 2nd edition (WRAML-II; Sheslow & Adams, 2003). The Verbal Memory and Visual Memory indices will be used in analyses.

Finally, academic achievement was assessed with the Revised Wide Range Achievement Test (WRAT-R; Jastak, Jastak, & Bijou, 1984). The three subtest scores of Word Reading, Math, and Spelling will be used in analyses.

Selection of covariates:

Based on prior literature (Noble, Norman, & Farah, 2005; Van Ijzendoorn, et al., 2008), potential covariates include child gender, region of adoption, age at testing, time spent in adoptive home, and adoptive parent education (as an estimate of the nature of the child's adoptive home environment). There was no significant correlation between age at testing and duration of orphanage experience, (r[143] = -.01, p = .90) indicating that children who had been adopted at a younger age were tested at a similar age, on average, as children who were adopted at an older age. There was a significant correlation observed between the time that was spent in the adoptive home and children's full-scale IQ, (*r*[135] = .18, *p* = .04). However, it is noted that time spent in the adoptive home is highly related to time spent in the orphanage, (*r*[141] = -.55, *p* < .001). Thus, in this sample, it is difficult to disentangle the unique contributions of time spent in orphanage and time spent in adoptive home (see Table 1 for a summary of Pearson correlation coefficients for demographic and time variables). Thus, it is deemed that in addition to duration of institutionalization (the predictor of interest), age at testing is a more appropriate covariate to use than time spent in adoptive home. Unfortunately, as mentioned above, adoptive parent education was not routinely assessed in this archival dataset and 30% (*n* = 43) of cases have missing data for this variable. Thus, parental education cannot regularly be used as a covariate among the entire sample. However, for participants whose parental education is known there was no significant correlation observed between the average of maternal and paternal adoptive parent education and child's full-scale IQ, (*r*[97] = .12, *p* = .25) and, additionally, adoptive parent education is not related to the time that the child spent in the orphanage (*r*[102] = -.13, *p* = .20). Despite the failure to find a significant relationship of parental education to these variables of interest in bivariate analyses, multivariate analyses will be run that include parental education as a covariate on the smaller subsample for which parental education data is available (presented in APPENDIX A).

Table 1: Inter-Correlation of Descriptive Variables

	Duration of Institutionalization	Age at Evaluation	Time in Adoptive Home
Age at Evaluation	-0.01		
Time in Adoptive Home	-0.50**	0.78**	
Parental Education	-0.13	-0.07	0.00

** Pearson correlation coefficient significant at the .01 level.

Data Analysis: Global Functioning (WISC Profile Analysis)

Two approaches will be employed to evaluate whether individual cognitive domains, as assessed by the WISC, demonstrate unique relations with duration of institutionalization. In order to evaluate multiple WISC outcomes simultaneously participants will be placed into one of three groups based on duration of institutionalization (<12 months [*n* = 32], 12-23 months [*n* = 52], and >23 months [*n* = 55]), and a repeated measures MANCOVA will be run to evaluate whether the three groups differ among the cognitive outcome measures. A particular interest will be paid to the multivariate interaction of duration group and cognitive outcomes. If a significant interaction is observed, it suggests that different cognitive domains (as measured by WISC subtests) demonstrate unique relationships with duration. This multivariate approach is particularly useful for the WISC indices, as they were all normed on the same sample making any observed differences among them more easily to interpret as characteristic of the current sample, rather than an artifact of test norms.

In addition to this multivariate approach to evaluate WISC subscales simultaneously, individual indices will be evaluated in isolation. In order to discern whether a linear or non-linear relationship best describes the relationship of each outcome domain with duration of institutionalization, a series of hierarchical regression analyses will be employed for each index. Each analysis will involve three models and a particular interest will be paid to the R^2 change across models. In the first model, the covariates (age at testing, gender, and region of adoption dummy coded as either South East Asia or Eastern Europe) will be entered. In the second and third models, the duration of institutionalization and subsequently the square of the duration of institutionalization will be entered. If a significant R^2 change is observed in the final step, this will suggest that particular index is better explained by a non-linear or threshold relationship with duration institutionalization, than it is by a linear relationship.

Finally, efforts will be made to determine which WISC indices demonstrate the strongest relationship with duration. Because we are evaluating whether any domains demonstrate nonlinear relationships with duration, and because the same model must be used for all outcomes in order to make a direct comparison, the combined linear, quadratic models will be compared. In order to control for covariates when comparing these correlations, initial regressions will be run for each outcome with the covariates as predictors and the residuals from these models will be saved. These residuals will then be used to get the impact of duration on the outcomes by running regressions for each outcome using the residuals as the dependent variable and the linear and quadratic terms for duration as the predictor. The Steiger test (Steiger, 2004) will then be used to compare the combined R of each of these regressions in an effort to determine statistical significance. So, for example, four outcomes will result in 6 pairwise comparisons. To control the overall Type I error a simple correction will be employed: observed p values will be ranked from smallest to largest and compared to a p of (.05 / number of comparisons). The next comparison will be compared to a p of (.05 / comparisons – 1), etc. As soon as one comparison is not significant it will be concluded that the remainder of the comparisons are not significant.

Because the sample was administered different versions of the WISC (79% took the WISC-III while 21% took the WISC-IV) and to maximize interpretability and confidence in results, analyses will be conducted with both the entire sample and the subgroup of participants who were assessed with the WISC-III (results of WISC-III subsample analyses are presented in Appendix B). Outcome measures when the entire sample is analyzed will include composite score and subtest scores that are comparable across the two versions of the test (full scale IQ, Vocabulary subtest, Block Design subtest, Coding subtest, and Digit Span subtests). The FSIQ of the WISC-III and the WISC-IV correlate highly (*r*=.89). The four subtests of interest are also highly correlated in test-retest reliability studies between the two tests (*r*=0.82, *r*=0.77, *r*=0.76, and *r*=0.77, respectively; Williams, Weiss & Rolfhus, 2003) with slightly inflated scores in the older norms, as is consistent with the Flynn effect (Flynn 1984, 1987). Analyses with the WISC-III sub-sample (APPENDIX B:) will evaluate the composite scores of VCI, POI, FDI, and PSI which are more reliable than the single subtest scores, as well as the 12 subtests that comprise the WISC-III core.

Data Analysis: Neuropsychological Measures

A similar approach as was used to evaluate the WISC subtests individually will be employed to evaluate the subsequent neuropsychological measures (including assessment of memory [verbal and nonverbal], language [receptive and expressive], executive functioning [sustained attention and impulse control], manual dexterity, and academic achievement [reading, math, and spelling]). Addition of more specific neuropsychological measures will, ideally, provide both convergent and discriminant validity to the observed WISC results. A series of hierarchical regression analyses will be employed for each cognitive domain. Again, each analysis will involve three models (covariates, duration of institutionalization, and finally the square of the duration of institutionalization) and a particular interest will be paid to the R^2 change across models.

In order to evaluate which WISC indices demonstrate the strongest relationship with duration, as was conducted with the WISC subscales, an *R* value will be obtained for the combined linear and quadratic models. As before, initial regressions will be run for each outcome with the covariates as predictors and the residuals from these models will be saved in order to control for covariates. These residuals will then be used to get the impact of duration on the outcomes by running regressions for each outcome using the residuals as the dependent variable and the linear and quadratic terms for duration as the predictor. Unfortunately, it becomes impractical to determine statistical significance of the magnitude of the difference between these *R* values, as comparing eleven neuropsychological measures would require 3.6 million pairwise comparisons.

RESULTS

Data Screening

Prior to analyses, predictor variable (duration of institutionalization), all outcome variables (WISC and neuropsychological measures), and all relevant descriptive variables (parental education, time in adoptive home, age at testing, region of orphanage, and gender) were evaluated for fit between their distributions and the assumptions of multivariate analysis. A natural log transformation of the duration institutionalization variable and the age at testing variable was performed in order to reduce observed positive skew of these variables. One participant's FSIQ was noted as a significant multivariate outlier in its relation with duration of institutionalization (this participant had an extremely low cognitive score, but relatively short duration of institutionalization). This participant's data was not included in further analyses.

The distributions of Grooved Pegboard dominant and nondominant hands, GDS Vigilance Hits and Vigilance False Alarms, and the combined variable of CELF Concepts and Directions/Token Test all demonstrated significant negative skew, and were reflected in order to conduct a natural log transformation (Grooved Pegboard and GDS) or square root transformation (Concepts and Directions/Token Test). After transformation but prior to analyses, all reflected distributions were reflected a second time in order to maintain the original direction of the distribution. Even after transformation, one significant outlier was observed for the GDS Vigilance Hits test. The individual GDS value for this participant was deleted from further analyses with this variable.

Bivariate Analyses

Prior to multivariate analyses, bivariate analyses were performed on all variables of interest. Table 2 presents the Pearson correlation coefficients for the available descriptive variables with the cognitive outcome measures. Participant's age at testing was significantly related to performance on the WISC Coding, Block Design, and Digit Span subtests, and to dominant handed Grooved Pegboard performance. Greater age at testing was associated with worse performance on these measures, relative to age-based comparison groups as published in test norms. Parental education was solely related to WISC Vocabulary scores, with greater parental education being associated with higher scores.

Table 2: Bivariate Pearson Correlations of Cognitive Measures with Descriptive Variables

	Pearson Correlation Coefficient				
	Age at Evaluation	Time in Adoptive Home	Parental Education	Duration of Institution.	Duration of Institution.^{2}
WISC-III & WISC-IV					
Full-Scale IQ	-0.10	0.18*	0.12	-0.41**	-0.43**
Coding	-0.19*	0.02	0.04	-0.26**	-0.27**
Block Design	-0.21*	0.04	0.01	-0.32**	-0.33**
Vocabulary	-0.04	0.25**	0.23*	-0.42**	-0.45**
Digit Span	-0.18*	0.05	0.06	-0.28**	-0.31**
CELF-IV & Token Test					
Producing Word Associations	0.07	0.21*	0.03	-0.29**	-0.29**
Concepts and Directions / Token Test	-0.10	0.25**	0.07	-0.48**	-0.50**
WRAML-II					
Verbal Memory	-0.07	0.13	0.19	-0.34**	-0.35**
Visual Memory	-0.07	-0.00	-0.05	-0.11	-0.10
WRAT-II					
Reading	-0.00	0.28**	0.09	-0.43**	-0.44**
Spelling	-0.05	0.21*	0.05	-0.40**	-0.42**
Mathematics	0.02	0.18*	0.15	-0.28**	-0.29**
Grooved Pegboard					
Dominant Hand	-0.29**	-0.14	0.08	-0.23**	-0.24**
NonDominant	-0.16	0.02	0.10	-0.28**	-0.27**
GDS Vigilance					
Hits	-0.03	0.02	0.02	-0.07	-0.07
False Alarms	0.10	0.23*	0.11	-0.29**	-0.28**

* Correlation is significant at the .05 level; ** Correlation is significant at the .01 level.

Table 3 summarizes observed differences between region of orphanage and participant gender. The region of the planet from which the participant was adopted predicts cognitive test performance for every measure included in the test battery, with the exception of the two GDS Vigilance tasks. There was a trend, across the board, for participants who had been adopted from Eastern Europe to score the lowest, followed by participants who had been adopted from Northern Asia, and finally, the strongest performance was observed in participants who had been adopted from South East Asia. These test performance scores parallel the mean duration that participants spent in the institution in each region; the greatest duration of institutionalization was observed among participants who were adopted from Eastern Europe, followed by participants who were adopted from Northern Asia and, finally, the least duration was observed among participants who were adopted from South East Asia. In this sample, female participants score significantly higher than male participants on the WISC Coding subtest, two language measures (Producing Word Associations and Concepts and Directions / Token Test) and the Mathematics subtest of the WRAT. These gender differences may be due, in part, to females having spent significantly less time in an institution than males and the fact that gender was not equally represented across region of adoption (χ^2[3,144] = 34.24, p < .01).

Table 3: Descriptive and Outcome Measures by Participant Gender and Region of Adoption.

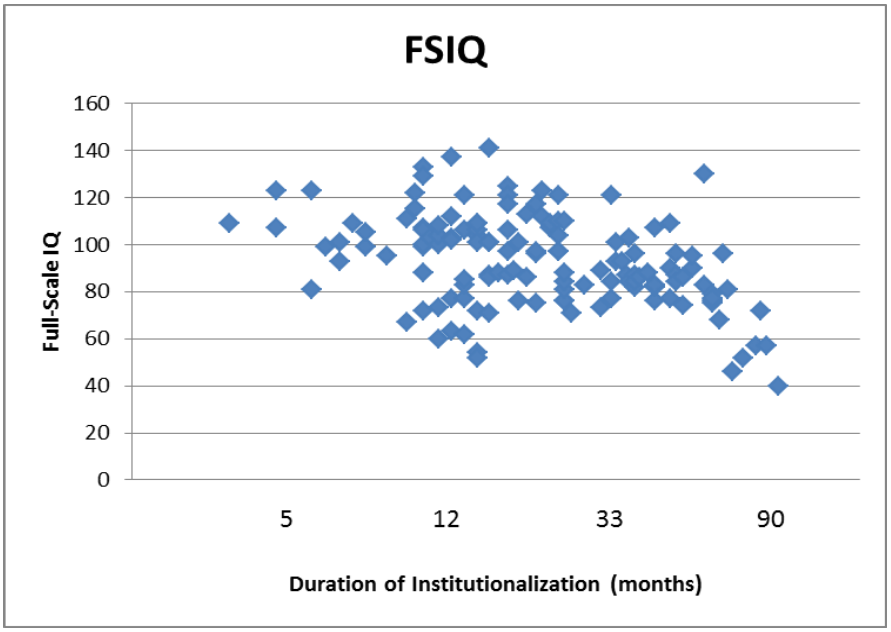
	Mean			Mean			
	Male	Female	F	Eastern Europe	Northern Asia	South/ East Asia	F
age at testing	9.01	9.69	3.60	9.93	9.30	8.91	2.55
months in orphanage	28.29	24.24	1.69	33.70	26.20	18.52	10.31***
parental education	17.04	16.59	1.25	16.66	16.68	16.87	0.11
months in adoptive home	77.85	90.81	5.57*	84.70	84.25	85.80	0.03
WISC-III & WISC-IV (standard or scaled scores)							
Full Scale IQ	90.89	94.81	1.35	82.42	93.04	103.53	14.92***
Coding	7.71	9.59	7.98**	6.51	8.31	11.57	23.38***
Block Design	9.37	9.28	0.02	7.67	9.20	11.00	8.10***
Vocabulary	8.74	9.13	0.40	7.44	9.18	10.07	6.39**
Digit Span	8.03	7.67	0.39	6.02	8.49	8.73	9.59***
CELF-IV & Token Test (T-scores)							
Producing Word Associations	48.42	53.60	5.09*	30.28	43.11	50.44	21.97***
Concepts and Directions / Token Test	38.70	44.00	4.07*	48.26	49.02	56.63	5.45**
WRAML-II (standard scores)							
Verbal Memory	84.92	87.96	0.80	77.54	86.20	94.07	8.49***
Visual Memory	89.73	92.32	0.69	84.43	92.23	96.32	4.98**
WRAT-II (standard scores)							
Reading	94.55	96.52	0.37	85.73	97.38	103.32	11.16***
Spelling	93.18	95.77	0.73	85.95	95.44	101.98	10.32***
Mathematics	87.98	95.24	4.20*	79.63	92.38	103.50	18.20***
Grooved Pegboard (T-scores)							
Dominant Hand	37.16	39.01	0.00	26.32	39.47	47.02	4.93**
Nondominant Hand	35.99	35.96	0.01	24.96	35.27	45.51	5.04**
GDS Vigilance (T-scores)							
Hits	42.40	35.77	2.95	36.48	40.68	36.63	0.78
False Alarms	32.34	32.80	0.78	29.29	32.58	33.64	1.40

* Mean difference is significant at the .05 level; ** Mean difference is significant at the .01 level
Note: Although mean values above describe central tendency of non-transformed variables; for variables with significant skew, difference statistic represents transformed distributions.

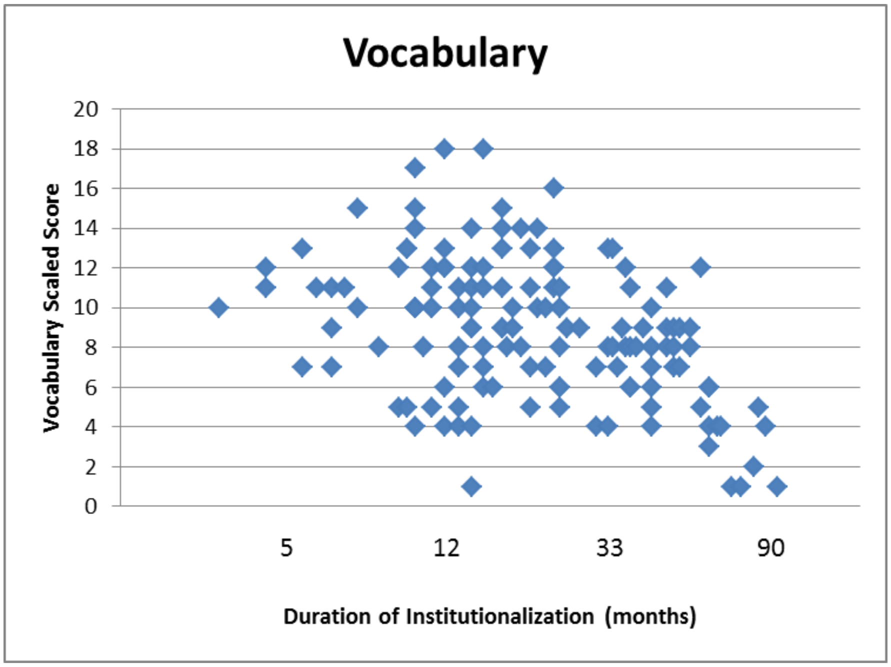
Table 2 and Table 5 summarize the bivariate relationship of duration of institutionalization with all cognitive outcome measures. Table 2 presents Pearson correlation coefficients of all measures with a *continuous* duration variable. With the exceptions of the WRAML-II Visual Memory composite and GDS Vigilance Hits task, all measures demonstrate a statistically significant relationship with duration. Across the board, increasing duration is associated with lower scores. The strongest relationship with duration is observed for the Concepts and Directions / Token Test subtest, with a Pearson correlation of -.48, followed by WRAT Reading, WISC Vocabulary, WISC Full-Scale IQ, and WRAT Spelling (with Pearson correlation coefficients of -.43, -.42, -.41, and -.40, respectively). Bivariate scatterplots of WISC measures with duration (one scatterplot each for FSIQ and the four WISC subtests) are presented in Figure 1 to provide a visual representation of a representative subset of these relationships.

Figure 1: Scatterplots of WISC FSIQ and subscales with duration of institutionalization

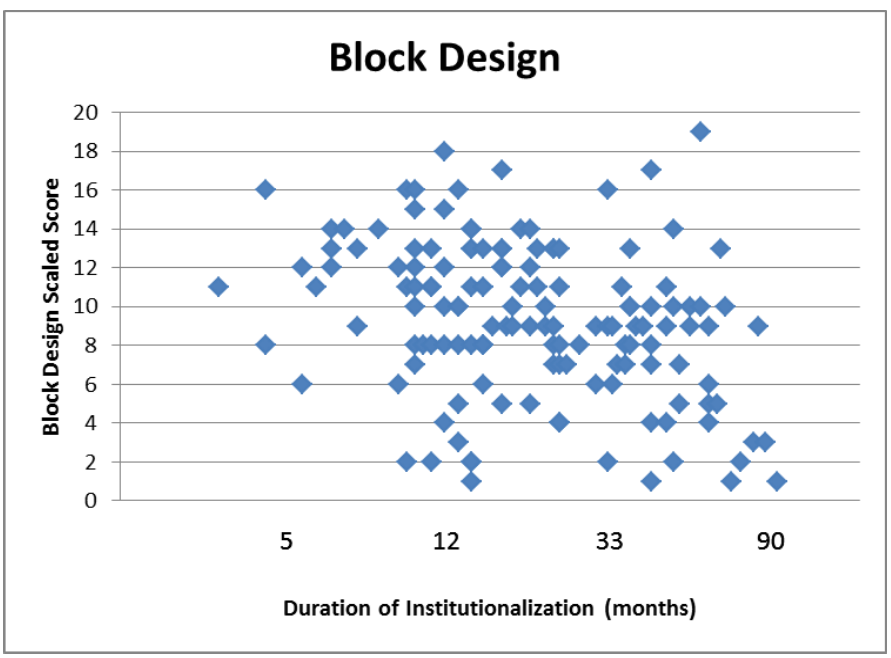
a. WISC Full-Scale IQ



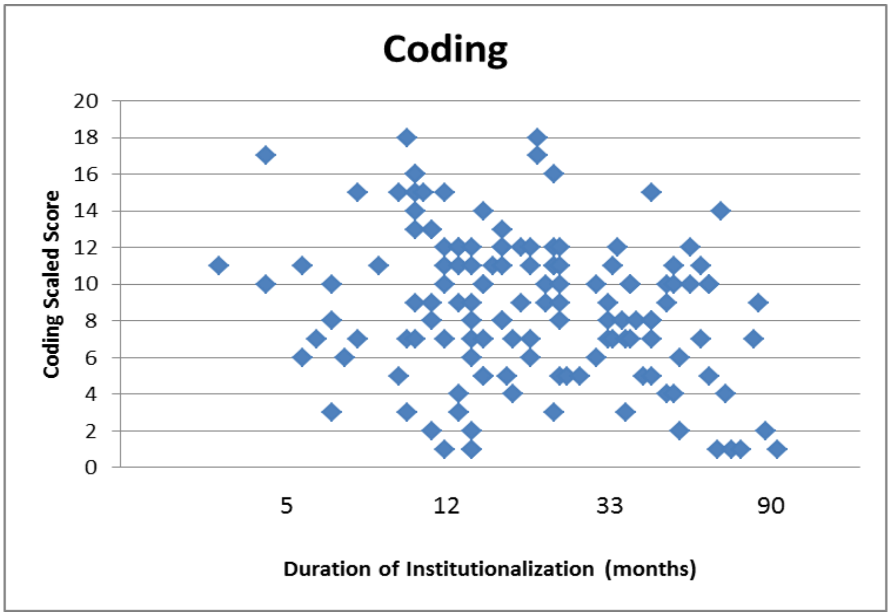
b. WISC Vocabulary



c. WISC Block Design



d. WISC Coding



e. WISC Digit Span

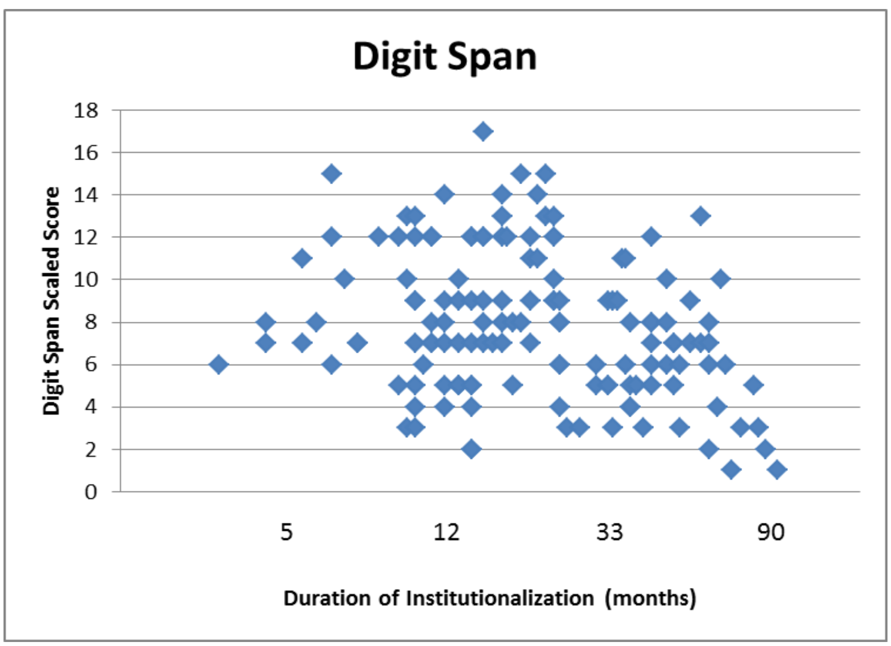


Table 2 also lists Pearson correlation coefficients of all measures with a non-linear term of duration^2. As with the linear term, the majority of the measures (with the same exceptions observed with the linear duration term – namely Visual Memory and GDS Vigilance Hits) demonstrate a significant relationship with the nonlinear duration^2 term. In order to determine whether the nonlinear term duration^2, predicts any unique variance after the variance accounted for by the linear duration term, a series of hierarchical regressions were run on all cognitive outcome measures using two models as predictors (duration in the first model and the combination of duration and duration^2 as predictors). Table 4 summarizes the results of these regressions. Inclusion of the nonlinear term duration^2 in the second model significantly improved prediction of the WISC Vocabulary and Digit Span subtests, and the Concepts and Directions / Token Test measures.

Table 4: Summary of Series of Hierarchical Regression Models with Duration and Duration^2 Predicting Cognitive Measures

Variable	Model 1: Duration		Model 2: Duration & Duration^2	
	R^2	F for ΔR^2	R^2	F for ΔR^2
WISC-III & WISC-IV				
Full-Scale IQ (N = 136)	.17**	26.67**	.19**	3.90
Coding (N = 140)	.07**	9.80**	.08**	1.69
Block Design (N = 140)	.10**	15.59**	.11**	1.03
Vocabulary (N=139)	.18**	29.57**	.23**	10.01**
Digit Span (N = 140)	.08**	11.88**	.13**	8.45**
CELF-IV / Token Test				
Producing Word Associations (N = 133)	.08**	12.02**	.09**	0.14
Concepts and Directions / Token Test (N = 131)	.23**	37.96**	.25**	4.24*
WRAML-II				
Verbal Memory (N = 124)	.12**	16.22**	.12**	0.59
Visual Memory (N = 122)	.01	1.44	.01	0.26
WRAT-II				
Reading (N = 135)	.18**	29.29**	.20**	2.80
Spelling (N = 134)	.16**	25.60**	.18**	2.48
Mathematics (N = 133)	.08**	10.91**	.08**	0.96
Grooved Pegboard				
Dominant Hand (N = 131)	.05*	6.87*	.07*	1.94
NonDominant (N = 131)	.08**	11.15**	.08**	0.62
GDS Vigilance				
Hits (N = 119)	.01	0.63	.01	0.06
False Alarms (N = 118)	.10**	13.24**	.11**	0.78

* Significant at the $\alpha = .05$ level; ** Significant at the $\alpha = .01$ level

Table 5 also summarizes the bivariate relationship of duration of institutionalization with cognitive outcome measures, this time with a *discrete* duration variable. Table 5 presents mean values for three discrete groups of participants classified by duration of institutionalization of less than 12 months, between 12 and less than 24 months, and greater than or equal to twenty four months. Identical to the results observed when duration was evaluated as a continuous measure, participant outcome differed significantly when evaluating these discrete groups of duration for most of the cognitive measures, with the exclusion of WRAML Visual Memory and GDS Vigilance Hits. When differences were observed, post-hoc tests were performed (also presented in Table 5). Post-hoc tests indicate that when a difference was observed between groups, the average performance of participants with the shortest duration of institutionalization was consistently lower than the average performance of participants with the longest duration of institutionalization (one exception being dominant hand performance on the Grooved Pegboard test - Although significant differences were observed in omnibus tests, no significant differences were observed in post-hoc tests using Tukey's criterion for a highly significant difference).

The mean values obtained on outcome measures for the discrete groups are presented in Table 5 (note that although mean values presented in the table describe the central tendency of non-transformed variables; for variables with significant skew, the reported difference statistic represents transformed distributions). Among the group of participants with the shortest duration (less than 12 months) the mean performance is within a standard deviation of the normative sample's mean performance with the exception of the Grooved Pegboard non-dominant hand performance, and the two GDS Vigilance tasks (the non-transformed mean values obtained for these measures fall in the Low Average range).

The mean cognitive performance for participants with the longest duration of institutionalization (two years or more in the orphanage) is more variable than it is for participants who had remained in the institution for less than 12 months. Non-transformed mean values were within a standard deviation of the normative sample mean for the WISC Coding and Block Design subtests, CELF Producing Word Associations subtest, the WRAML Visual Memory subtest, and the WRAT Reading and Spelling subtests. Non-transformed mean performance for the remainder of the measures was a standard deviation or more below the normative sample mean. The non-transformed mean value was particularly low for performance on the dominant hand of the Grooved Pegboard Test, WRAML Verbal Memory, the CELF Concepts and Directions/Token Test (the non-transformed mean values for these three measures fall in the Borderline range); and for the non-dominant hand of the Grooved Pegboard Test, and the GDS False Alarms measures (non-transformed mean values for these two measures fall in the Impaired range).

Table 5: Cognitive Outcome Measures by Participants Grouped by Duration of Institutionalization

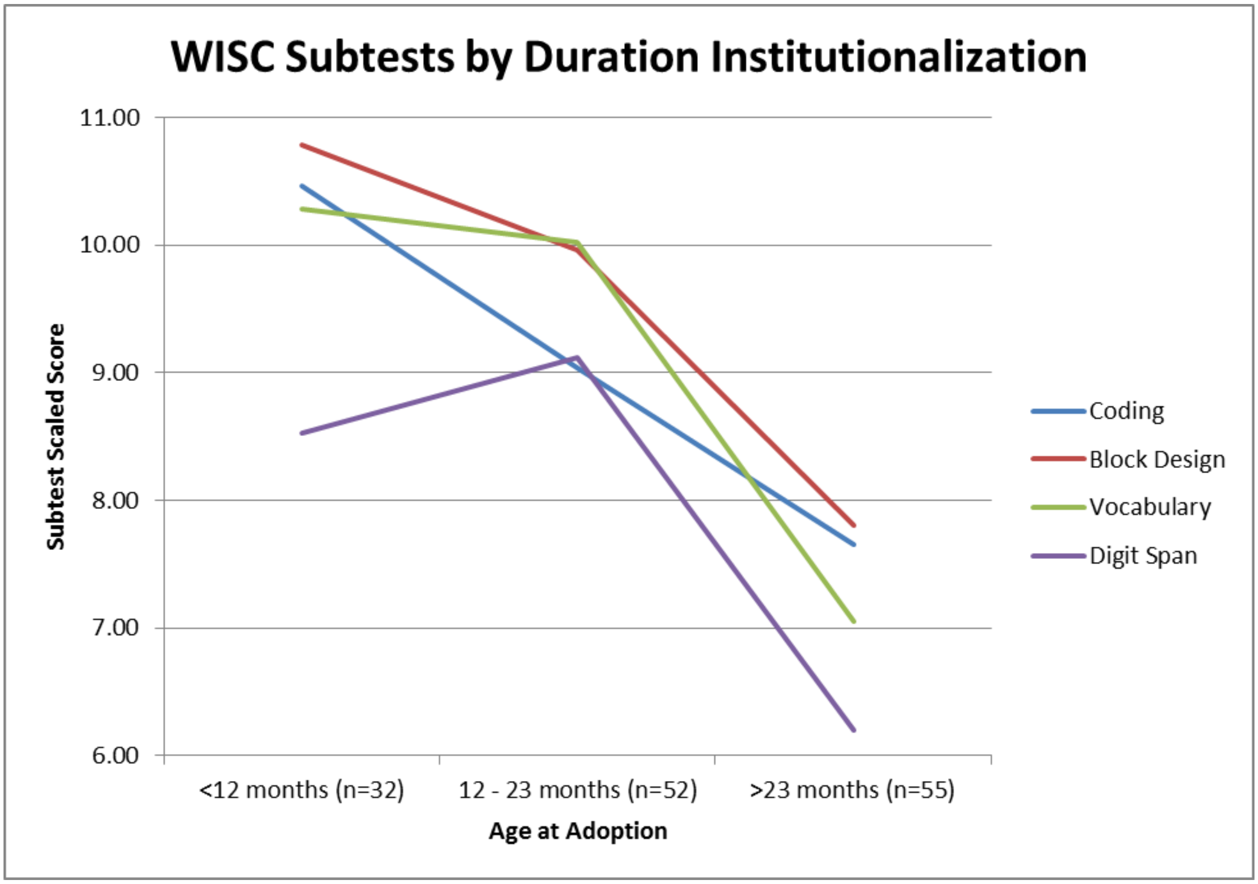
Outcome Measure	(N)	A: duration < 12 mos Mean ± SD	(N)	B: duration >= 12 & < 24 Mean ± SD	(N)	C: duration >= 24 Mean ± SD	Difference Statistic F	Tukey HSD
WISC-III & WISC-IV (standard or scaled score)								
Full Scale IQ	(30)	101.37 ± 17.57	(51)	97.90 ± 19.78	(55)	83.73 ± 16.12	12.59**	A > C; B > C
Coding	(32)	10.47 ± 4.45	(52)	9.04 ± 4.06	(56)	7.59 ± 3.35	5.76**	A > C
Block Design	(32)	10.78 ± 3.62	(52)	9.96 ± 3.86	(56)	7.84 ± 3.98	7.16**	A > C; B > C
Vocabulary	(32)	10.28 ± 3.08	(52)	10.02 ± 3.62	(55)	7.05 ± 2.93	14.95**	A > C; B > C
Digit Span	(32)	8.53 ± 3.15	(52)	9.12 ± 3.52	(56)	6.20 ± 2.74	12.70**	A > C; B > C
CELF-IV & Token Test (T-scores)								
Producing Word Associations	(30)	57.67 ± 15.11	(52)	51.96 ± 12.53	(51)	47.35 ± 11.86	25.31**	A > C
Concepts and Directions & Token Test	(30)	49.77 ± 11.35	(51)	47.24 ± 15.59	(50)	31.22 ± 13.43	6.09**	A > C; B > C
WRAML-II (Standard Scores)								
Verbal Memory	(31)	92.87 ± 17.87	(46)	91.59 ± 19.06	(47)	77.55 ± 15.01	10.35**	A > C; B > C
Visual Memory	(30)	94.00 ± 19.68	(46)	90.61 ± 15.44	(46)	89.67 ± 16.22	0.63	
WRAT-II (Standard Scores)								
Reading	(31)	105.23 ± 15.22	(53)	99.19 ± 16.39	(51)	85.20 ± 17.07	16.85**	A > C; B > C
Spelling	(31)	102.26 ± 14.63	(53)	98.58 ± 14.68	(50)	85.04 ± 16.19	15.52**	A > C; B > C
Mathematics	(31)	97.45 ± 17.41	(53)	94.85 ± 20.71	(49)	84.69 ± 19.12	5.25**	A > C; B > C
Grooved Pegboard (T-scores)								
Dominant Hand	(32)	43.16 ± 24.27	(51)	37.53 ± 38.88	(49)	35.16 ± 24.44	3.12*	*n.s.*
Nondominant Hand	(32)	40.00 ± 25.53	(50)	40.27 ± 22.11	(49)	28.59 ± 34.93	3.09*	A > C
GDS Vigilance (T-scores)								
Hits	(29)	37.93 ± 25.55	(46)	37.57 ± 27.47	(45)	38.80 ± 17.91	0.24	
False Alarms	(29)	37.00 ± 34.28	(45)	35.96 ± 27.47	(44)	25.89 ± 30.06	5.25**	A > C

* Mean difference is significant at the .05 level; ** Mean difference is significant at the .01 level.

WISC Subscale profile analysis (Vocabulary, Block Design, Coding, Digit Span)

In order to simultaneously evaluate the relation of the four representative WISC subtests with duration of institutionalization, while also accounting for covariates, a three (duration group of either <12 months, 12-23 months, or >23 months) by four (WISC subtest score – Vocabulary, Block Design, Coding, or Digit Span) repeated measures MANCOVA was performed on the entire sample. The overall test with gender, age at testing, and region of orphanage entered as covariates revealed a significant effect of duration on the combined outcomes, with greater duration being associated with lower WISC performance ($F[2,132] = 5.63$, $p < .01$). Using Wilks' criterion, a significant duration group by subtest score interaction was also observed ($F[6, 262] = 2.60$, $p < .05$) suggesting nonparallel slopes for the four subtests. This result is depicted in Figure 2. This interaction has a medium effect size (Cohen, 1988) with a partial eta-squared of 0.06.

Figure 2: WISC Subtests by Duration of Institutionalization



A series of hierarchical regressions were run in order to further understand the relationship of the WISC subtests with duration of institutionalization, while considering the covariates gender, age at evaluation, and region of adoption. Table 6 presents a summary of the results of each of these regressions, including R^2, and *F*-statistic for R^2 change. Addition of the duration of institutionalization (step 2) made a significant improvement in the models (after accounting for the covariates of age at testing, gender, and region of orphanage) for FSIQ, Block Design, Vocabulary, and Digit Span but not for the Coding subtest. Addition of the third step of the regression, inclusion of the nonlinear term duration of institutionalization squared, resulted in significant improvement for FSIQ, Vocabulary, and Digit Span but not for Coding or Block Design. (See **Error! Reference source not found.** in Appendix C for a summary of individual β values for predictors in each step of the models.)

A comparison of the results obtained when covariates are (Table 6) and are not (Table 4) included in the hierarchical regression models indicates that addition of covariates reduces the predictive power of duration to non-significance for the WISC Coding subtest. When considering the impact that inclusion of covariates made on the nonlinear term duration^2, the predictive power of FSIQ was increased to the significant level only when covariates were considered. Consideration of covariates did not change interpretation of results for any of the other WISC measures.

Finally, in order to determine which WISC subtest(s) are most strongly related to duration of institutionalization, the Steiger test was used to compare the strength of the correlation between the residual of the covariates regressed on each individual subtest as the outcome and the combined linear and quadratic terms for duration as the predictor. The observed R for the combined linear and quadratic regressions (listed in order of strength) was $R = .41$ for Vocabulary, $R = .31$ for Digit Span, $R = .25$ for Block Design and $R = .17$ for Coding. The strongest relationship between WISC Subscale and duration (observed for the Vocabulary subtest) was significantly stronger than the observed relationship for either Coding or Block Design ($z[143] = -2.9$, $p < .01$; $z[146] = 2.8$, $p < .01$).

Neuropsychological Measures

As was applied with the WISC subtests, a series of hierarchical regressions were run for each neuropsychological outcome of interest using a continuous variable of duration of institutionalization as the predictor. Results for individual neuropsychological measures (including R^2, and F-statistic for R^2 change) are presented in Table 6. Most neuropsychological measures administered demonstrate a significant relationship with duration, even after accounting for covariates. These include language measures (Producing Word Associations and Concepts and Directions/Token Test), WRAML-II Verbal memory, WRAT Reading and Spelling, non-dominant hand performance on the Grooved Pegboard test, and GDS Vigilance False Alarms. Measures that did not demonstrate a relation with duration include the WRAML visual memory, WRAT Mathematics, Dominant hand performance on the Grooved Pegboard test, and GDS Vigilance Hits. (See Table 18 through Table 22 in Appendix C for a summary of individual β values for predictors in each step of the models.)

A comparison of the results obtained when covariates are (Table 6) and are not (Table 4) included in the hierarchical regression models indicates that addition of covariates reduces the predictive power of duration to non-significance for the WRAT Mathematics subtest and the

Grooved Pegboard dominant hand task. Inclusion of covariates does not change the predictive power of any of the neuropsychological measures in the third model (inclusion of the predictor duration^2).

Table 6: Summary of Series of Hierarchical Regression Models with Covariates, Duration, and Duration^2

Predicting Cognitive Measures

Variable	Model 1: Covariates'		Model 2: Covariates' & Duration		Model 3: Covariates' & Duration & Duration^2	
	R^2	F for ΔR^2	R^2	F for ΔR^2	R^2	F for ΔR^2
WISC-III & WISC-IV						
Full Scale IQ (*n* = 136)	.19**	7.83**	.27**	12.97**	.29**	4.93*
Coding (*n* = 140)	.28**	12.78**	.28**	1.76	.30**	2.23
Block Design (*n* = 140)	.14**	5.44**	.19**	8.56**	.20**	1.16
Vocabulary (*n* = 139)	.09*	3.43*	.21**	19.67**	.26**	9.44**
Digit Span (*n* = 140)	.14**	5.30**	.18**	6.73*	.22**	8.10**
CELF-IV / Token Test						
Producing Word Associations (*n* = 133)	.09*	3.21*	.10**	6.60*	.10**	0.39
Concepts and Directions & Token Test (*n* = 131)	.26**	10.89**	.36**	20.17**	.38**	4.01*
WRAML-II						
Verbal Memory (*n* = 124)	.12**	3.98**	.18**	8.64**	.18**	0.87
Visual Memory (*n* = 122)	.05*	2.51*	.08	0.05	0.08	0.24
WRAT-II						
Reading (*n* = 135)	.16**	6.13**	.26**	16.97**	.28**	3.29
Spelling (*n* = 134)	.14**	5.42**	.23**	14.61**	.25**	2.69
Mathematics (*n* = 133)	.23**	9.69**	.25**	2.64	.26**	1.68
Grooved Pegboard						
Dominant Hand (N = 131)	.17**	6.29**	.19**	3.77	.20**	1.11
NonDominant (N = 131)	.10**	3.59**	.14**	5.79*	.15**	0.84
GDS Vigilance						
Vigilance Hits (*n* = 119)	.06	1.84	.06	0.40	.07	0.17
Vigilance False Alarms (*n* = 118)	.04	1.19	.12*	10.60**	.13*	0.36

* Significant at the α = .05 level; ** Significant at the α = .01 level

' Covariates include participant age at testing, gender, and region of adoption.

The correlation between the residual of the covariates regressed on each individual subtest and the combined linear and quadratic terms for duration are depicted in Table 7. Relationships that reach statistical significance, listed beginning with the strongest magnitude, include the Concepts and Directions/Token Test (R = .38), WRAT Reading and Spelling (R = .35 and R = .33, respectively), GDS Vigilance False Alarms (R = .28), WRAML Verbal Memory (R = .26), and CELF Producing Word Associations (R = .21).

Table 7: *R* value for the combined Duration and Duration2 values predicting the residual of the covariates (including gender, age at evaluation, and region of adoption) regressed on each cognitive outcome measure

Variable	R
WISC-III & WISC-IV	
Full Scale IQ (*n* = 136)	0.34**
Coding (*n* = 140)	0.17
Block Design (*n* = 140)	0.25**
Vocabulary (*n* = 139)	0.41**
Digit Span (*n* = 140)	0.31**
CELF-IV / Token Test	
Producing Word Associations (*n* = 133)	0.21*
Concepts and Directions & Token Test (*n* = 131)	0.38**
WRAML-II	
Verbal Memory (*n* = 124)	0.26*
Visual Memory (*n* = 122)	0.05
WRAT-II	
Reading (*n* = 135)	0.35**
Spelling (*n* = 134)	0.33**
Mathematics (*n* = 133)	0.17
Grooved Pegboard	
Dominant Hand (N = 131)	0.19
NonDominant (N = 131)	0.21
GDS Vigilance	
Vigilance Hits (*n* = 119)	0.07
Vigilance False Alarms (*n* = 118)	0.28*

* Significant at the α = .05 level; ** Significant at the α = .01 level

DISCUSSION

In this study, a sample of 144 children with a history of institutional upbringing is examined. The sample provides a picture on the sequelae of institutionalization including the long-term effects of experience-expectant and experience-dependent deprivation during early childhood. The purpose of this study is to evaluate the relationship of *duration* of institutional experience with child cognitive functioning after adoption into a family home. Participants in this study were placed in an orphanage immediately after release from a hospital (for a duration of institutionalization ranging from 3 to 90 months), and are assessed in middle childhood after an average stay of 7 years in an adoptive family home (average age at assessment was 9 years). The two primary aims evaluated in this study are: 1) which cognitive domains demonstrate the strongest relationship with duration of institutionalization and 2) whether different cognitive domains demonstrate unique relations with duration of institutionalization.

The study finds that increased duration of institutionalization is related to decreased performance for a number of cognitive domains, even after consideration of the covariates of gender, age at testing, and region of adoption. Domains of functioning that are most consistently implicated include verbal measures (WISC Vocabulary, CELF Producing Word Associations, Concepts and Directions/Token Test, WRAML Verbal Memory, and WRAT Reading and Spelling) and executive Functioning measures (GDS Vigilance Hits and WISC Digit Span but not GDS Vigilance False Alarms). The relationships with duration for measures requiring visual-spatial skills are more mixed and a visual reasoning task is found to significantly relate to duration (Block Design) but not a measure of visual memory (WRAML Visual Memory) or a measure of mathematics computations (WRAT Mathematics). There is little evidence to support a relationship between the duration of institutionalization and fine-motor dexterity (no significant relationship is observed for Grooved Pegboard non-dominant hand performance or for WISC Coding; Grooved Pegboard Dominant hand performance is significant in multivariate regression using duration as a predictor, but falls to non-significance in regression using combined variables of duration and duration^2 as predictor). These results suggest that institutionalization exerts a dose-response influence on *select* domains of child cognition. A relationship between duration and cognitive outcome is also reported in numerous other samples (Ames, 1997; Behen, et al., 2008; Le Mare, Audet, & Kurytnik, 2007; Morison & Ellwood, 2000; O'Connor, et al., 2000; Sloutsky, 1997a). Chiefly, it is clear that efforts should be taken to minimize a child's exposure to institutional care.

These results indicate that the duration of institutional experience is a strong predictor of child cognitive outcome across many, but not all, cognitive domains. The existence of trend differences of duration with different cognitive outcome is most compelling when evaluating the slopes of four WISC subtests simultaneously; even though these subtests are normed on the same population; different subtests demonstrate different shapes in relation to duration of institutionalization. Although longer duration of institutionalization affects many cognitive domains, it does not exert a pervasive and uniform influence. In agreement with this finding, several studies find specific impairments to be related to a history of institutionalization independent of global IQ (Behen, et al., 2008; Colvert et al., 2008; Stevens et al., 2008). Theoretically, it makes sense that cognitive domains would demonstrate unique relations with the duration of deprivation, as it is known that different brain regions mature at different periods in development (Huttenlocher & Dabholkar, 1997), and thus, are likely to demonstrate unique periods when they are most sensitive to environmental input.

The strongest relationships with duration are observed for language measures (WISC Vocabulary, CELF Concepts and Directions/Token Test, WRAT Reading and Spelling) followed by executive functioning measures (WISC Digit Span and GDS Vigilance False Alarms). This parallels previous findings from our sample (Behen, et al., 2008) as well as other reports to suggest that while institutionalization has the potential to relate to pervasive, cross-domain, impairment; language (Beckett, et al., 2010; Croft, et al., 2007; N. A. Fox, Almas, Degnan, Nelson, & Zeanah, 2011) and executive functioning (K. J. Bos, Fox, Zeanah, & Nelson Iii, 2009; Colvert, et al., 2008) are domains that are likely to be impacted by increased duration of institutional care. Interestingly, one study finds that the best predictor of a child's eventual cognitive outcome is the presence of even very minimal language skills at the time of adoption (Croft, et al., 2007). Additionally, executive functioning has been reported to mediate many of the behavioral syndromes associated with institutionalization (Colvert, et al., 2008). Interestingly, language and executive functioning are also the cognitive domains that are most strongly related to being raised in a low socioeconomic environment, another example of environmental deprivation (Noble, et al., 2005) suggesting that these domains may be most sensitive to environmental influences.

In addition to evaluating which measures demonstrate the strongest relationship with duration, the shape of the relationship was also evaluated in order to determine whether a non-linear (vs linear) decrease in cognitive performance was observed in relation to duration of institutionalization. A duration of two years has been reported as a potential threshold for cognitive functioning in several prior studies (Dennis, 1973; C. A. Nelson, 3rd et al., 2007) as would be observed if the relationship were better represented by a non-linear fit. In this sample, some but not all of the measures are best represented by a nonlinear relationship with duration. For language measures, including a measure of language knowledge (WISC Vocabulary), and a measure of receptive vocabulary (Concepts and Directions/Token Test), a nonlinear relationship is observed with progressively lower scores observed with increased time of duration. A nonlinear relationship is also observed for a measure of verbal working memory (Digit Span). Visual inspection of scatter plots suggests that the threshold (or asymptote) for these trends occurs after approximately two years of duration.

When evaluating the sample in this study, the greatest confidence for nonlinearity is observed among *verbal* measures, as nonlinearity is found when parental education is included as a covariate (APPENDIX A: Analyses Repeated on Sub-Set of Sample Including Parental Education as a Covariate) and for numerous verbal subscales of the WISC (APPENDIX B:). These results may demonstrate a sensitive period in language development for children with a history of institutional care that occurs around approximately two years of age. One possible explanation for these findings may be that language in the first two years of life is preserved, or protected, in the face of adverse experience, to a point. Indeed, previous researchers have found that among individuals with early brain injury, verbal functions may be more plastic than nonverbal functions because language is dependent on a dense network of interlocking neural systems (Stiles, et al., 2002), although this plasticity is not without cost and "some price must be paid for wholesale reorganization of the brain to compensate for early injuries" (Elizabeth Bates, 2005, p. 205). Thus, it is important to note that the observance of a nonlinear relationship does not imply that there is a "safe" duration that a child may experience institutional care prior to experiencing related deficits. Rather, these results demonstrate that the experience of institutionalization predicts lower cognitive functioning across many domains, and particularly for language. The relationship between duration and language functioning becomes increasingly more detrimental after approximately two years.

It is important to note that there are inconsistencies in prior literature in that numerous studies have failed to observe a non-linear or threshold effect between duration and outcome (see, for example, O'Connor, et al., 2000) and some studies even fail to find a significant relationship between duration and outcome at all (Beckett, et al., 2006; Van Ijzendoorn, et al., 2008). One explanation for the discrepant findings in these studies may be due to the differing methodologies that are employed between studies. Many prior studies include children who were placed in an institution at a later age (after early experience of family life) or children with as little as two weeks of orphanage experience (see argument by Maclean, 2003). Indeed, Van Ijzendoorn et al report a significant effect of age at placement, with children placed in an orphanage before 12 months of age performing significantly less well than children who entered the orphanage after 12 months. A significant strength of the current sample is that all participants were required to have been placed in an institution immediately upon release from the hospital, eliminating the experience of early familial care as a potential confound.

This study is also unique in the relatively large number of participants who experienced more than two years of institutional experience prior to adoption. Maclean (2003) notes that the great majority of children adopted since 1990 have been adopted before the age of 2, making it difficult to study children with longer-duration of orphanage experience. The sample that is employed in this study is uniquely situated to explore questions about duration, as a significant number of our participants had institutional experience lasting past two years of age (72 children in the current study's sample were adopted after age 20 months). Additionally, prior research to evaluate neuropsychological profiles in children with a history of institutionalization excludes children whose global intellectual functioning is in the borderline-impaired or impaired ranges (Behen, et al., 2008; Pollak, et al., 2010). This study, however, sought to evaluate the comprehensive profile of cognitive functioning using continuous measures of duration of institutionalization as well as discrete groupings of participants.

It should be noted that because this study does not employ a never-institutionalized comparison group, interpretation of these results is constrained to answer questions about the relationship that *duration* of institutionalization has when evaluating children with a known history of institutionalization. Future studies to employ a matched comparison group will prove beneficial in further delineating cognitive profiles of children with a history of institutionalization. Because tests that were employed in this study have been normed on large samples of typically developing children, examination of the mean cognitive scores obtained by participants who are grouped by discrete groups of duration experienced (<12 months, 12-24 months, >24 months) provides a measure of the relative functioning of these children. Some interesting and apparently contradictory findings are observed to demonstrate the importance of the distinction between evaluating the *duration* of institutionalization vs. institutionalization per se. For example, as reported above, there was no significant relation observed between duration of institutionalization and dominant handed motor dexterity; however, the average performance for the lower duration groups on these measures falls in the Low Average (as opposed to Average) range. Additionally, a measure of impulsivity was not found to demonstrate a significant relationship with duration; however, the mean score for participants with 12-24 months of institutional experience was in the Borderline range. And finally, even though a significant multivariate relationship was observed between expressive language and duration, the average expressive language score for participants with two years or more duration of institutionalization on a test of expressive language was in the Average range.

The inclusion of child's age at evaluation, gender, and region of adoption as covariates is supported in bivariate analyses; older age at testing was related to poorer performance on select outcome measures; females significantly outperformed males on select measures; and significant differences in performance were observed depending on the region of the planet from which the child was adopted. These factors are interrelated in our sample. For instance, females tended to spend less time in an institution prior to adoption and gender was not evenly represented among children adopted from different regions. Future analyses are needed to understand the unique impact that these variables play on a child's outcome.

Although it was not a focus of this study, the specific role that the child's adoptive environment plays in fostering resilience in the face of institutionalization remains an interesting question. In this sample, the duration of time that a child spent in his/her adoptive home is significantly related to better cognitive performance on a number of measures in bivariate analyses. However, it is also noted that more time spent in an adoptive home is significantly predictive of a shorter duration of institutional experience and to a greater age at evaluation, making the unique relation that the time spent in adoptive home has with outcome difficult to disentangle in this sample. The relationship that adoptive parent education has with child outcome is also evaluated for a subset of the sample (Appendix A). In bivariate analyses parent education is not significantly related to outcome measures, with the exception of the WISC Vocabulary subtest. In analyses that include parental education as a covariate, parental education fails to add any unique variance to the multivariate models for any outcome measure, including the Vocabulary subtest. These null results are unexpected, as the quality of the caretaking environment has been demonstrated to be a strong predictor of child cognitive outcome in numerous studies (Bradley, Caldwell, & Rock, 1988) and are likely explained by a restricted range of parental education in this sample (this was a particularly well-educated sample with mean parental education greater than 16 years). A limitation of this study is that most of the families are middle class, but even within single socioeconomic stratum there are variations in proximal caregiving, something this study did not evaluate. In future studies it will be important to see how these variations support or derail a child's recovery.

The study of sensitive periods is a remarkably complex endeavor. It is important to keep in mind that individual cognitive and behavioral domains develop in dynamic synchrony with one another, and thus it is misleading to study development of a singular system in isolation of the surrounding brain regions (Fischer & Bidell, 2006; Neville & Bavelier, 1999). However, these results indicate that different cognitive domains do, in fact, demonstrate unique relations with duration of institutionalization; and some, but not all, are better represented by a non-linear, or threshold, model than by a linear model. Future studies to evaluate the relation of neuropsychological functioning to duration of institutionalization should employ longitudinal analyses and never institutionalized comparison groups in conjunction with evaluation of proximal caregiving environment.

APPENDIX A: Analyses Repeated on Sub-Set of Sample Including Parental Education as a Covariate

Because parental education was not available for approximately 30% of participants, parental education was not included as a covariate in the primary analyses of this project, despite numerous prior studies demonstrating the importance of the quality of the family's socioeconomic status (including parent education as an important component of socioeconomic status) in predicting child outcome (see, for example, Duyme, Dumaret, & Tomkiewicz, 1999; McLoyd, 1998). In order to increase confidence in the results reported in the primary analyses above, herein analyses were rerun including parental education as a covariate for the subset of participants whose parental educational status was known (*n* = 101). Bivariate relationships (presented in the results section of the primary manuscript, Table 2) suggest that the only outcome that was significantly related to parental education was the WISC Vocabulary subtest.

A three (duration group of either <12 months [*n* = 28], 12-23 months [*n* = 40], or >23 months [*n* = 32]) by four (WISC subtest score – Vocabulary, Block Design, Coding, or Digit Span) repeated measures MANCOVA was performed on the sub-sample of participants for whom parental education was known. The overall test with gender, age at testing, region of orphanage, and parental education entered as covariates revealed a significant effect of duration on the combined outcomes ($F[2,92] = 3.61$, $p < .05$). Thus, the combined WISC subscales are significantly, and negatively, related to duration whether or not parental education is included as a covariate. Using Wilks' criterion, a significant duration group by subtest score interaction was also observed ($F[6, 180] = 2.67$, $p < .05$) suggesting nonparallel slopes for the four subtests. This interaction has a medium effect size (Cohen, 1988) with a partial eta-squared of 0.08.

These results suggest that parental education does not explain the non-uniform relation with duration of institutionalization that was observed among the four WISC subscales. However, it is not known whether the same WISC subtests are driving the observed results in the two analytical approaches. A series of hierarchical regressions performed on each subtest will help to explore whether inclusion of parental education as a covariate will change interpretation of results obtained in primary analyses. It is impossible to make a direct comparison, however, as the fewer number of participants for whom parental education is available, in addition to the greater number of covariates included in analyses, provides for significantly less power to observe significant differences. Thus, failure to observe significant differences may be due to a lack of a true difference, or it may be due to a lack of power to observe the difference.

Table 8 presents a summary of a series of hierarchical regression models predicting WISC and neuropsychological measures with the five covariates (gender, region of adoption, age at evaluation, and parental education) entered as predictors in the first models, duration of institutionalization added in the second, and finally duration of institutionalization^2 entered in the third models. Of the second models, duration of institutionalization made a significant improvement in the prediction of WISC FSIQ and Vocabulary, Concepts and Directions / Token Test, WRAT Reading, non-dominant handed performance on the Grooved Pegboard Test, and GDS Vigilance False Alarms. Measures that were not significant in these analyses, but were significant in the primary analyses of the manuscript include the Block Design and Digit Span subtests from the WISC, the Producing Word Associations subtest of the CELF, WRAML Verbal Memory, and WRAT Spelling. Note, however, that parental education was not a significant contributor for any of these regressions (see Table 9 through Table 15 for a summary of β values for predictors).

In the third model of the series of hierarchical regressions (also presented in Table 8), duration of institutionalization^2 made a significant improvement in the model for the WISC Vocabulary subtest. Measures that were not significant in these analyses, but were significant in the primary analyses of the manuscript include the WISC FSIQ and Digit Span subtest, and the CELF Concepts and Directions subtest. Again, parental education was not a significant contributor in the model for any of these measures (see Table 9 through Table 15 for a summary of β values for predictors).

In sum, these analyses accounting for the influence of parental education on participant cognitive outcome do not provide evidence to contradict the conclusions reached in the primary analyses of this manuscript. Importantly, among the second and third models, parental education was not a significant contributor for any outcome. Further, even among this smaller sample with an additional covariate, not all cognitive measures demonstrate a uniform relationship with duration. It was found that verbal functioning, in particular, demonstrates a non-linear relationship with duration.

Table 8 Summary of Series of Hierarchical Regression Models with Covariates', Duration, and Duration^2 Predicting Cognitive Measures

Variable	Model 1: Covariates'		Model 2: Covariates' & Duration		Model 3: Covariates' & Duration & Duration^2	
	R^2	F for ΔR^2	R^2	F for ΔR^2	R^2	F for ΔR^2
WISC-III & WISC-IV						
Full Scale IQ (*n* = 97)	.20**	4.50**	.24**	4.94*	.25**	0.60
Coding (*n* = 101)	.27**	7.03**	.27**	0.16	.27**	0.04
Block Design (*n* = 101)	.18**	4.03**	.20**	3.06	.20**	0.11
Vocabulary (*n* = 100)	.12*	2.47*	.19**	8.23**	.23**	4.42*
Digit Span (*n* = 101)	.15**	3.47**	.17**	1.53	.19**	2.81
CELF-IV / Token Test						
Producing Word Associations (*n* = 97)	.05	1.05	.09	3.60	.09	0.01
Concepts and Directions & Token Test (*n* = 98)	.25**	5.98**	.35**	14.94**	.36**	1.48
WRAML-II						
Verbal Memory (*n* = 94)	.11	2.18	.15*	3.62	.15	0.15
Visual Memory (*n* = 94)	.07	1.34	.07	0.11	.08	0.50
WRAT-II						
Reading (*n* = 99)	.14*	3.06*	.19**	5.70*	.20**	0.71
Spelling (*n* = 99)	.14*	3.14*	.17**	2.69	.17*	0.12
Mathematics (*n* = 99)	.16**	3.65**	.17**	0.22	.17*	0.09
Grooved Pegboard						
Dominant Hand (*n* = 96)	.15**	4.41**	.21**	0.92	.22**	0.22
NonDominant (*n* = 96)	.05	2.02	.09**	4.98*	.09**	1.18
GDS Vigilance						
Vigilance Hits (*n* = 94)	.12*	2.50*	.12	0.01	.13	0.36
Vigilance False Alarms (*n* = 93)	.09	1.75	.15*	6.28*	.16*	1.12

* Significant at the α = .05 level; ** Significant at the α = .01 level

' Covariates include participant age at testing, gender, region of adoption, and parental education.

Table 9: Summary of β values for predictors in series of hierarchical Regression Analyses

Predicting WISC FSIQ

Variable and Predictors	Model 1	Model 2	Model 3
Full Scale IQ (*n* = 97)	β	β	β
Age at Testing	-0.04	-0.06	-0.05
Gender	-0.12	-0.11	-0.11
SE Asia	0.36**	0.28*	0.29*
E Europe	-0.17	-0.12	-0.11
Parental Education	0.09	0.06	0.05
Ln Duration Institutionalization		-0.23*	0.25
Ln Duration Institutionalization^2			-0.49

* Significant at the α = .05 level; ** Significant at the α = .01 level

Table 10: Summary of β values for predictors in series of hierarchical Regression Analyses Predicting WISC subtests

Variable and Predictors	Model 1	Model 2	Model 3
Coding (*n* = 101)	β	β	β
Age at Testing	-0.08	-0.08	-0.08
Gender	0.03	0.03	0.03
SE Asia	0.39***	0.37**	0.38**
E Europe	-0.17	-0.16	-0.16
Parental Education	0.02	0.02	0.01
Ln Duration Institutionalization		-0.04	0.08
Ln Duration Institutionalization^2			-0.12
Block Design (*n* = 101)	β	β	β
Age at Testing	-0.18	-0.19	-0.19
Gender	-0.17	-0.15	-0.15
SE Asia	0.34**	0.28*	0.29*
E Europe	-0.04	-0.01	-0.00
Parental Education	-0.04	-0.06	-0.06
Ln Duration Institutionalization		-0.17	0.06
Ln Duration Institutionalization^2			-0.24
Vocabulary (*n* = 100)	β	β	β
Age at Testing	-0.00	-0.02	-0.00
Gender	-0.11	-0.08	-0.07
SE Asia	0.18	-0.08	0.11
E Europe	-0.16	-0.09	-0.05
Parental Education	0.21*	0.17	0.13
Ln Duration Institutionalization		-0.30**	1.01
Ln Duration Institutionalization^2			-1.34*
Digit Span (*n* = 101)	β	β	β
Age at Testing	-0.19	-0.20	-0.19
Gender	-0.23*	-0.22	-0.22*
SE Asia	0.10	0.05	0.08
E Europe	-0.22*	-0.20	-0.17
Parental Education	0.01	0.00	-0.02
Ln Duration Institutionalization		-0.13	0.94
Ln Duration Institutionalization^2			-1.08

* Significant at the α = .05 level; ** Significant at the α = .01 level

Table 11: Summary of β values for predictors in series of hierarchical Regression Analyses Predicting the language measures Producing Word Associations and Concepts and Directions/Token Test

Variable and Predictors	Model 1	Model 2	Model 3
Producing Word Associations (*n* = 97)	β	β	B
Age at Testing	0.05*	0.05	0.05
Gender	-0.00	0.02	0.02
SE Asia	0.25*	0.18	0.18
E Europe	0.06	0.10	0.10
Parental Education	0.02	-0.02	-0.02
Ln Duration Institutionalization		-0.22	-0.15
Ln Duration Institutionalization^2			-0.07
Concepts and Directions / Token Test (*n* = 98)	β	β	B
Age at Testing	-0.05	-0.06	-0.05
Gender	-0.13	-0.09	-0.09
SE Asia	0.28*	0.15	0.16
E Europe	-0.33**	-0.25*	-0.23*
Parental Education	0.04	-0.02	-0.04
Ln Duration Institutionalization		-0.37**	0.32
Ln Duration Institutionalization^2			-0.70

* Significant at the α = .05 level; ** Significant at the α = .01 level

Table 12 Summary of β values for predictors in series of hierarchical Regression Analyses

Predicting WRAML-II Verbal and Visual Memory

Variable and Predictors	Model 1	Model 2	Model 3
WRAML-II Verbal Memory (*n* = 94)	β	β	B
Age at Testing	-0.01	-0.02	-0.02
Gender	-0.12	-0.11	-0.11
SE Asia	0.22	0.15	0.15
E Europe	-0.14	-0.10	-0.10
Parental Education	0.17	0.15	0.14
Ln Duration Institutionalization		-0.21	0.05
Ln Duration Institutionalization ^{2}			-0.26
WRAML-II Visual Memory (*n* = 94)	β	β	B
Age at Testing	-0.00	-0.00	-0.01
Gender	-0.04	-0.04	-0.04
SE Asia	0.22	0.23	0.22
E Europe	-0.10	-0.11	-0.11
Parental Education	-0.06	-0.06	-0.05
Ln Duration Institutionalization		0.04	-0.46
Ln Duration Institutionalization^2			0.50

* significant at the α = .05 level; ** Significant at the α = .01 level

Table 13: Summary of β values for predictors in series of hierarchical Regression Analyses Predicting WRAT Reading, Spelling, and Mathematics

Variable and Predictors	Model 1	Model 2	Model 3
WRAT Reading (*n* = 99)	β	β	B
Age at Testing	-0.03	-0.04	-0.04
Gender	-0.27*	-0.24*	-0.24*
SE Asia	0.30*	0.22	0.23
E Europe	-0.14	-0.09	-0.08
Parental Education	0.04	0.01	-0.01
Ln Duration Institutionalization		-0.25*	0.29
Ln Duration Institutionalization^2			-0.55
WRAT Spelling (*n* = 99)	β	β	B
Age at Testing	-0.13	-0.14	-0.14
Gender	-0.23*	-0.21	-0.21
SE Asia	0.27*	0.22	0.22
E Europe	-0.12	-0.08	-0.07
Parental Education	0.01	-0.02	-0.03
Ln Duration Institutionalization		-0.17	0.05
Ln Duration Institutionalization^2			-0.23
WRAT Mathematics (*n* = 99)	β	β	B
Age at Testing	0.05	0.05	0.05
Gender	-0.14	-0.13	-0.13
SE Asia	0.37**	0.35**	0.36**
E Europe	-0.13	-0.12	-0.11
Parental Education	0.12	0.11	0.11
Ln Duration Institutionalization		-0.05	0.14
Ln Duration Institutionalization^2			-0.20

* significant at the α = .05 level; ** Significant at the α = .01 level

Table 14 Summary of β values for predictors in series of hierarchical Regression Analyses

Predicting Grooved Pegboard Test dominant and nondominant hands

Variable and Predictors	Model 1	Model 2	Model 3
Grooved Pegboard Dominant Hand (*n* = 96)	B	β	B
Age at Testing	-0.36**	-0.36**	-0.36**
Gender	-0.03	-0.02	-0.02
SE Asia	0.03	0.00	0.01
E Europe	-0.15	-0.13	-0.12
Parental Education	0.07	0.05	0.04
Ln Duration Institutionalization		-0.10	0.21
Ln Duration Institutionalization^2			-0.31
Grooved Pegboard Nondominant Hand (*n* = 96)	B	β	B
Age at Testing	-0.08	-0.09	-0.10
Gender	-0.07	-0.04	-0.05
SE Asia	0.27*	0.19	0.17
E Europe	-0.06	-0.01	-0.03
Parental Education	0.09	0.06	0.08
Ln Duration Institutionalization		-0.24	-0.96
Ln Duration Institutionalization^2			0.73

* significant at the α = .05 level; ** Significant at the α = .01 level

Table 15 Summary of β values for predictors in series of hierarchical Regression Analyses

Predicting GDS Vigilance Hits and False Alarms

Variable	Model 1	Model 2	Model 3
GDS Vigilance Hits (*n* = 94)	β	β	β
Age at Testing	0.08	0.08	0.08
Gender	-0.35**	-0.35**	-0.35**
SE Asia	0.07	0.06	0.05
E Europe	-0.28*	-0.28*	-0.29*
Parental Education	-0.03	-0.03	-0.02
Ln Duration Institutionalization		-0.01	-0.41
Ln Duration Institutionalization^2			0.41
GDS Vigilance False Alarms (*n* = 93)	β	β	β
Age at Testing	0.25*	0.24*	0.22*
Gender	-0.13	-0.11	-0.11
SE Asia	0.20	0.11	0.09
E Europe	-0.14	-0.08	-0.10
Parental Education	0.11	0.06	-0.09
Ln Duration Institutionalization		-0.28*	-0.98
Ln Duration Institutionalization^2			0.71

* significant at the α = .05 level; ** Significant at the α = .01 level

APPENDIX B: Profile Analysis of WISC-III Index Scores (Sub-Group of Total Sample)

Because the sample was administered different versions of the WISC (79% took the WISC-III while 21% took the WISC-IV) and to maximize interpretability and confidence in the results obtained in the primary analyses of this manuscript, analyses herein will be repeated with the subgroup of participants who took the WISC-III.

A three (duration group of either <12 months [n = 22], 12-23 months [n = 37], or >23 months [n = 44]) by four (WISC composite score – Verbal Comprehension Index, Perceptual Organizational Index, Processing Speed Index, and Freedom from Distractibility Index) repeated measures MANCOVA was performed on the sub-sample of participants who were administered the WISC-III (n = 103). The overall test with gender, age at testing, and region of orphanage entered as covariates revealed a marginal effect of duration on the combined outcomes that was not significant at the .05 level ($F[2,96] = 2.53$, $p = .09$). Using Wilks' criterion, we also found a marginal effect of duration group by subtest score interaction that fell just short of statistical significance ($F[6, 188] = 2.13$, $p = .06$); however, this interaction demonstrated a medium effect size (Cohen, 1988) with a partial eta-squared of 0.06.

The WISC-III composite scores and all of the WISC-III subtest scores were evaluated for the presence of linear or nonlinear trends using a series of hierarchical regressions. As in the primary analyses of the manuscript; in Model 1 the covariates of gender, region of orphanage, and age at testing were entered. In model 2, the duration of institutionalization was added, and in model 3 the nonlinear term duration of institutionalization squared was included. Table 16 presents a summary of the results of each of these regressions and lists the F statistic for R^2 change.

Table 16: Summary of F for Change in R^2 Across Hierarchical Regression Models Predicting WISC-III Indices and Subtests

Variable	Model 1: Covariates'		Model 2: Covariates' & Duration		Model 3: Covariates' & Duration & $Duration^2$	
	R^2	F for ΔR^2	R^2	F for ΔR^2	R^2	F for ΔR^2
Full Scale IQ (*n* = 103)	.24**	7.67**	.31**	10.29**	.33**	2.81
VIQ (*n* = 102)	.21**	6.52**	.30**	12.12**	.34**	6.30*
PIQ (*n* = 102)	.24**	7.73**	.28**	5.13*	.29**	0.72
VCI (*n* = 105)	.19**	5.78**	.29**	14.55**	.34**	7.42**
Information (*n* = 105)	.16**	4.81**	.26**	13.14**	.31**	7.08**
Similarities (*n* = 105)	.19**	5.88**	.29**	13.71**	.32**	4.56*
Vocabulary (*n* = 104)	.15**	4.24**	.26**	15.43**	.30**	5.67*
Comprehension (*n* = 100)	.12*	3.36*	.14*	2.18	.16*	1.87
POI (*n* = 105)	.19**	5.73**	.22**	4.08*	.22**	0.38
Picture Completion (*n* = 104)	.16**	4.70**	.19**	3.08	.19**	0.19
Block Design (*n* = 105)	.18**	5.40**	.23**	7.25**	.24**	0.62
Picture Arrangement (*n* = 103)	.11*	2.95*	.12*	1.35	.13*	0.60
Object Assembly (*n* = 102)	.13*	3.54*	.15**	2.57	.15*	0.18
FDI (*n* = 105)	.19**	5.89**	.27**	10.09**	.29**	2.87
Arithmetic (*n* = 104)	.20**	6.30**	.26**	8.10**	.28**	1.66
Digit Span (*n* = 105)	.15**	4.43**	.22**	9.40**	.25**	3.10
PSI (*n* = 103)	.28**	9.57**	.29**	1.00	.29**	0.06
Coding (*n* = 105)	.29**	10.22**	.31**	2.49	.32**	1.84
Symbol Search (*n* = 102)	.19**	5.64**	.19**	0.37	.19**	0.29

* significant at the .05 level; ** Significant at the α = .01 level

' Covariates include participant age at testing, gender, and region of adoption.

Addition of duration of institutionalization (step 2) made a significant improvement in the models (after accounting for the covariates of age at testing, gender, and region of orphanage) for FSIQ, POI, VCI, and FDI but not for PSI. Addition of the third step of the regression, inclusion of the nonlinear term duration institutionalization squared, resulted in significant improvement for VCI only. These results indicate that longer duration of orphanage exposure prior to adoption predicts lower global IQ, VCI, POI, and FDI but not PSI. Additionally, the relationship of duration with VCI is nonlinear (with increasing negative slope of scores observed with increasing duration) even after accounting for any linear relationship.

These results obtained herein with a smaller sub-sample using the composite scores of the WISC-III are similar to the results obtained with representative subtests (Vocabulary, Block Design, Coding, and Digit Span) among the total sample in the primary analyses of this manuscript. Both these results and those reported above suggest that longer duration of institutionalization predicts lower composite IQ, verbal, visual-spatial reasoning, and working memory performances (VCI/Vocabulary, POI/Block Design, WMI/Digit Span); but, does not predict lower performance on tasks requiring rapid visual scanning and fine motor output (PSI/Coding). Additionally, a significant nonlinear relationship with duration was observed for verbal functioning among both samples (VCI /Vocabulary). One notable difference between these two analyses is the failure to find a nonlinear relationship for working memory (WMI) among participants who took the WISC-III, as compared with the significant nonlinear relationship that was observed in the total sample (for the Digit Span subtest). This failure may be due to the smaller sample size of participants administered the WISC-III in the analyses with the WMI which provides less power for statistical analyses.

The regression analyses repeated on all of the WISC-III subtest scores help to further elucidate how duration relates to specific cognitive tasks (summarized in Table 16). Inclusion of duration of institutionalization significantly improved the prediction of subtests from the VCI (Information, Similarities, Vocabulary, but not Comprehension), POI (among this index, only the Block Design subtest was significantly predicted), and FDI (both Arithmetic and Digit Span). Prediction of all subtests comprised in the VCI that demonstrated to relate to duration (including Information, Similarities, and Vocabulary) was significantly improved after inclusion of a nonlinear term (duration institutionalization squared).

APPENDIX C: Tables Summarizing β Values for Predictors in Hierarchical Regression Analyses to Predict WISC and Neuropsychological Measures (Analyses Conducted in Primary Section of Manuscript Employing Total Sample of Participants)

Table 17: Summary of β values for predictors in series of hierarchical Regression Analyses Predicting WISC FSIQ and representative subtests

Variable	Model 1	Model 2	Model 3
Full Scale IQ (*n* = 136)	β	β	β
Age at Testing	-0.01	-0.04	-0.03
Gender	-0.06	-0.05	-0.06
SE Asia	0.28**	0.20*	0.23*
E Europe	-0.25**	-0.20*	-0.19*
Ln Duration Institutionalization		-0.29***	0.86
Ln Duration Institutionalization ^{2}			-1.16*
Coding (*n* = 139)	β	β	β
Age at Testing	-0.11	0.11	-0.11
Gender	0.06	0.07	0.06
SE Asia	0.33***	0.30**	0.32**
E Europe	0.22**	-0.20*	-0.19*
Ln Duration Institutionalization		-0.1	0.67
Ln Duration Institutionalization ^{2}			-0.77
Block Design (*n* = 139)	β	β	β
Age at Testing	-0.12	-0.13	-0.13
Gender	-0.13	-0.12	-0.12
SE Asia	0.26*	0.19	0.20*
E Europe	-0.15	-0.11	-0.1
Ln Duration Institutionalization		-0.24**	0.36
Ln Duration Institutionalization 2			-0.61
Vocabulary (*n* = 138)	β	β	β
Age at Testing	0.02	-0.01	0.01
Gender	-0.05	-0.02	-0.04
SE Asia	0.14	0.04	0.08
E Europe	-0.23*	-0.17	-0.14
Ln Duration Institutionalization		-0.37***	1.2*
Ln Duration Institutionalization ^{2}			-1.2**
Digit Span (*n* = 139)	β	β	β
Age at Testing	-0.12	-0.12	-0.12
Gender	-0.14	-0.13	0.15
SE Asia	0.1	0.03	0.07
E Europe	-0.29**	-0.26**	-0.23**
Ln Duration Institutionalization		-0.23*	1.31*
Ln Duration Institutionalization ^{2}			-1.54**

Table 18: Summary of β values for predictors in series of hierarchical Regression Analyses Predicting the language measures Producing Word Associations and Concepts and Directions/Token Test

Variable and Predictors	Model 1	Model 2	Model 3
Producing Word Associations (*n* = 133)	β	β	B
Age at Testing	0.11	0.10	0.11
Gender	0.07	0.09	0.09
SE Asia	0.22*	0.15	0.16
E Europe	-0.07	-0.04	-0.03
Ln Duration Institutionalization		-0.23*	0.12
Ln Duration Institutionalization ^{2}			-0.35
Concepts and Directions / Token Test (*n* = 131)	β	β	B
Age at Testing	-0.01	-0.02	-0.01
Gender	-0.01	0.03	0.03
SE Asia	0.24*	0.14	0.16
E Europe	-0.35***	-0.29**	-0.27**
Ln Duration Institutionalization		-0.35***	0.63
Ln Duration Institutionalization ^{2}			-0.98*

* Significant at the α = .05 level; ** Significant at the α = .01 level

Table 19: Summary of β values for predictors in series of hierarchical Regression Analyses Predicting WRAML-II Verbal and Visual Memory

Variable	Model 1	Model 2	Model 3
WRAML-II Verbal Memory (*n* = 124)	β	β	B
Age at Testing	0.01	-0.00	0.01
Gender	-0.05	-0.03	-0.03
SE Asia	0.23*	0.15	0.17
E Europe	-0.20*	-0.16	-0.16
Ln Duration Institutionalization		-0.26**	0.29
Ln Duration Institutionalization ^{2}			-0.55
WRAML-II Visual Memory (*n* = 122)	β	β	B
Age at Testing	-0.01	-0.01	-0.02
Gender	-0.00	-0.00	0.00
SE Asia	0.13	0.13	0.12
E Europe	-0.19	-0.19	-0.19
Ln Duration Institutionalization		-0.02	-0.31
Ln Duration Institutionalization^2			0.29

* significant at the α = .05 level; ** Significant at the α = .01 level

Table 20: Summary of β values for predictors in series of hierarchical Regression Analyses Predicting WRAT Reading, Spelling, and Mathematics

Variable	Model 1	Model 2	Model 3
WRAT Reading (*n* = 135)	β	β	Β
Age at Testing	0.11	0.09	0.11
Gender	-0.12	-0.10	-0.11
SE Asia	0.25*	0.16	0.19
E Europe	-0.28**	-0.23**	-0.21*
Ln Duration Institutionalization		-0.33***	0.63
Ln Duration Institutionalization^2			-0.97
WRAT Spelling (*n* = 134)	β	β	Β
Age at Testing	0.04	0.03	0.04
Gender	-0.07	-0.04	-0.06
SE Asia	0.24*	0.16	0.18
E Europe	-0.24*	-0.19*	-0.18
Ln Duration Institutionalization		-0.31***	0.57
Ln Duration Institutionalization^2			-0.89
WRAT Mathematics (*n* = 133)	β	β	Β
Age at Testing	0.13	0.12	0.13
Gender	-0.05	-0.04	-0.04
SE Asia	0.33**	0.30**	0.32**
E Europe	-0.27**	-0.25**	-0.23*
Ln Duration Institutionalization		-0.13	0.55
Ln Duration Institutionalization^2			-0.69

* significant at the α = .05 level; ** Significant at the α = .01 level

Table 21: Summary of β values for predictors in series of hierarchical Regression Analyses

Predicting Grooved Pegboard Test dominant and nondominant hands

Variable	Model 1	Model 2	Model 3
Grooved Pegboard Dominant Hand (*n* = 131)	B	β	B
Age at Testing	-0.28**	-0.28**	-0.28**
Gender	-0.02	-0.00	-0.01
SE Asia	0.06	0.02	0.04
E Europe	-0.20*	-0.18	-0.17
Ln Duration Institutionalization		0.16	0.47
Ln Duration Institutionalization^2			-0.63
Grooved Pegboard Nondominant Hand (*n* = 131)	B	β	B
Age at Testing	-0.08	-0.08	-0.09
Gender	-0.12	-0.10	-0.10
SE Asia	0.23*	0.17	0.15
E Europe	-0.15	-0.12	-0.13
Ln Duration Institutionalization		-0.21*	-0.71
Ln Duration Institutionalization^2			0.51

* significant at the α = .05 level; ** Significant at the α = .01 level

Table 22: Summary of β values for predictors in series of hierarchical Regression Analyses Predicting GDS Vigilance Hits and False Alarms

Variable	Model 1	Model 2	Model 3
GDS Vigilance Hits (*n* = 119)	β	β	β
Age at Testing	0.02	0.02	0.01
Gender	-0.20	-0.20	-0.20
SE Asia	-0.04	-0.06	-0.06
E Europe	-0.20*	-0.19	-0.20
Ln Duration Institutionalization		-0.06	-0.31
Ln Duration Institutionalization^2			0.25
GDS Vigilance False Alarms (*n* = 117)	β	β	β
Age at Testing	0.13	0.13	0.13
Gender	0.00	0.02	0.02
SE Asia	0.13	0.05	0.05
E Europe	-0.04	0.01	0.01
Ln Duration Institutionalization		-0.28**	-0.37
Ln Duration Institutionalization^2			0.09

* significant at the α = .05 level; ** Significant at the α = .01 level

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ABSTRACT

NEUROPSYCHOLOGICAL OUTCOME IN RELATION TO DURATION OF EARLY ORPHANAGE EXPERIENCE

by

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In this sample of 144 children with a history of prior orphanage experience, increasing duration of institutionalization is related to decreasing performance for a number of cognitive domains, most consistently verbal measures and executive Functioning measures. The relationships with duration for measures requiring visual-spatial skills were more mixed and a visual reasoning task was found to significantly relate to duration but not a measure of visual memory or a measure of nonverbal achievement. There was little evidence to support a relationship between the duration of institutionalization and fine-motor dexterity. The strongest relationships with duration were observed for language measures followed by executive functioning measures. In addition to evaluating which measures demonstrate the strongest relationship with duration, the shape of the relationship was also observed. In this sample, some but not all of the measures were best represented by a nonlinear relationship with duration. For language measures, including a measure of language knowledge and a measure of receptive vocabulary, a nonlinear relationship was observed with increasingly lower scores observed with increasing duration. A nonlinear relationship was also observed for a measure of verbal working memory. These results may demonstrate a sensitive period in

language development for children with a history of institutional care that occurs around approximately two years of age.

AUTOBIOGRAPHICAL STATEMENT

Jacquie earned a Bachelor's degree from Washington University in St Louis where she majored in Psychology and minored in Music. After graduating, Jacquie spent time working for AmeriCorps St Louis Partners where she designed character-education programs for school children, and helped high-risk children learn to read. During her tenure at Washington University she was fortunate to have the opportunity to work on several cutting-edge research projects, including neuroimaging studies of schizophrenia and major depression; studies investigating predictors of functional communication in individuals with acquired aphasia; and studies examining the contribution of executive function to memory for older adults. Due, in part, to these research experiences; as well as her experiences growing up with a sibling with cerebral palsy; and her interest in working with high-risk populations, she decided that she would like to pursue a graduate career in pediatric neuropsychology.

Jacquie enrolled in Wayne State University's program in Clinical Psychology in the fall of 2005. At Wayne State University Jacquie studied the cognitive outcomes of children who were born preterm and has been involved in functional neuroimaging studies of children with Tourette Syndrome. This dissertation evaluating comprehensive neuropsychological functioning in children with a history of institutionalization, represents a synthesis of her interests in working with children and families as well as further understanding brain-environment-behavior relationships.